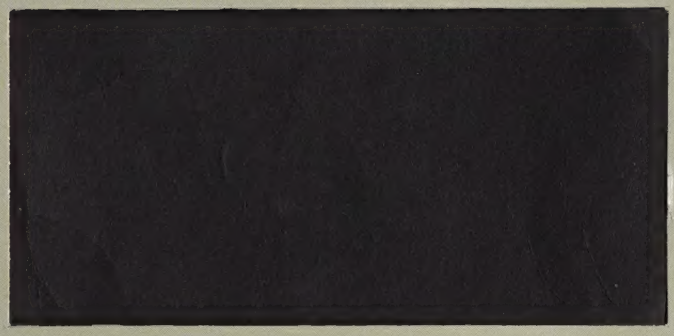

DANA™

Dana Laboratories Incorporated
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980323

# PRELIMINARY
# 2615
# DATA AMPLIFIER

DANA™

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June, 1968

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# SECTION 1

# INTRODUCTION

## 1.1 INTRODUCTION

The Dana Model 2615 Data Amplifier (Figure 1.1) is a low-level DC instrumentation amplifier providing a single wideband (40 kHz, minimum) output. The amplifier delivers ±10 volts full scale output; full scale current output is 15mA. It is suitable for driving medium-power recorders, passive filters, and display devices.

## 1.2 OPERATIONAL DESCRIPTION

All instrumentation amplifiers are confronted with the problem of common mode voltage — the voltage existing between each of a pair of input lines and common. This common mode voltage is amplified with the differential input voltage — the voltage across the two differential inputs. The result, of course, is inaccurate measurements of the differential input voltage. Dana Amplifiers use a separate Common Mode Amplifier to maintain this effect at a minimum.

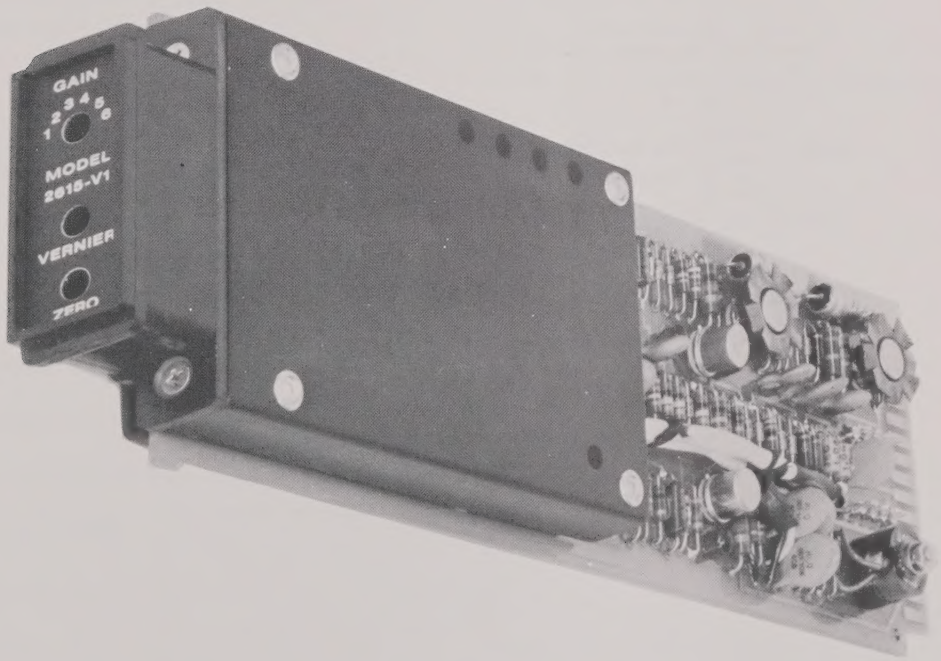


Figure 1.1 - Dana 2615 Data Amplifier

Figure 1.2 is a block diagram of Model 2615. The Normal Mode amplifier is a differential amplifier that amplifies the differential input voltage. Common mode voltage is effectively "cancelled out" in the Normal Mode amplifier by the output of the Common Mode amplifier. The common mode amplifier does this by sensing the common mode component of the signal in the first stage of the Normal Mode amplifier and supplying an opposing voltage. The output amplifier consists of direct-coupled circuitry that supplies the output voltage of the instrument. The output also is applied to the Normal Mode amplifier through the attenuator to complete the feedback circuit.

Amplifier gain is set by a voltage divider in the feedback circuit (Attenuator). Sets of precision resistors are switched into this circuit with each position of the GAIN switch.

## 1.3 GAIN OPTIONS

Two combinations of gain settings are available and must be specified when ordering the amplifier. They are designated as options V1, and V3.

1.3.1 Option V1. This option provides gain positions of 20, 50, 100, 200, 500, and 1000. A vernier adjustment extends each range by a factor of 2.5. This provides continuous selection of gains from 20 to 2500.

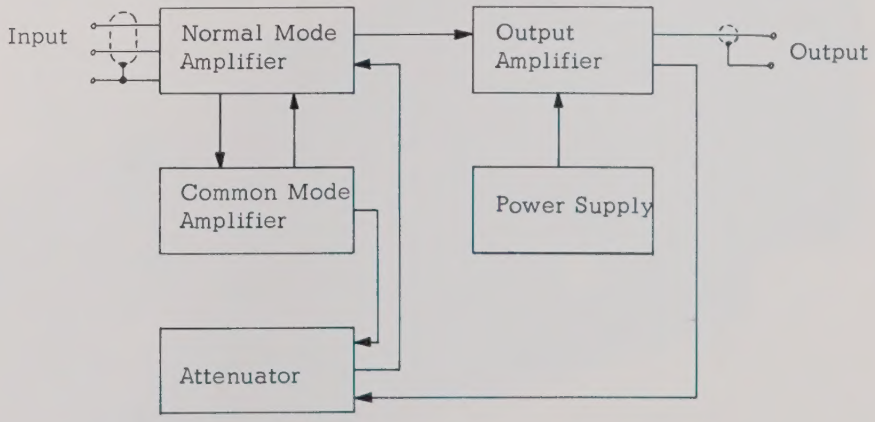


Figure 1.2 - Block Diagram, Model 2615

## Table 1.1 - Specifications

All specifications apply with sources of up to 350 ohms, in any unbalance.

| | |
|---|---|
| **GAIN** | |
| Steps | 20, 50, 100, 200, 500, 1000 |
| Vernier | Continuously variable up to 2.5 times step gain |
| Accuracy | ±0.1% |
| Resolution | ±0.1% (worst case) |
| **OUTPUT** | |
| Capability | ±10V, 15 mA, DC to 40 kHz |
| Resistance | 200 milliohms DC to 100 Hz |
| Capacitive Load | .05 uF without instability |
| Short Circuit Current | Short circuit proof, output current limited to approximately ±30 mA |
| **COMMON MODE** | |
| Rejection at K = 1000 | 120 dB DC to 60 Hz |
| Voltage | ±10V operating DC to 60 Hz<br>±60V no damage<br>Stable with open common mode return |
| **WIDEBAND NOISE, RTI AT K = 1000** | 4 uV RMS |
| **ZERO DRIFT** | 1 uV/°C RTI ±100 uV/°C RTO |
| Long Term | ±2 mV RTO in 200 hours |
| **LINEARITY** | ±.02% DC to 100 Hz |
| **BANDWIDTH** | ±1dB DC to 20 kHz |
| Minimum 3 dB frequency | 40 kHz |
| **INPUT RESISTANCE** | 10 megohms, minimum |
| **SETTLING TIME** | 500 usec to final value ±.1% F.S. |
| **OVERLOAD RECOVERY** | |
| 500% | 2 msec. to final value ±.1% F.S.<br>±10 uV RTI |
| 10V | 10 msec to final value ±.1% F.S.<br>±10 uV RTI |
| **POWER REQUIREMENTS** | ±28V ±10% at 35 mZ |

1.3.2 Option V3. This option provides gain positions of 100, 200, 500, 1000, 2000, and 5000. A vernier adjustment extends each range by a factor of 2.5. This provides continuous gains from 100 to 12,500.

## 1.4 SPECIFICATIONS

Specifications are listed in Table 1.1.

## 1.5 LOW-GAIN CONSIDERATIONS

For easier evaluation of accuracy pertinent specifications are tabulated in Table 1.2 — in terms of percentage of full scale.

Table 1.2

| Gain Setting | Zero Drift/Degree C as % of Full Scale | Error/Volt (Common Mode as % of Full Scale |
|---|---|---|
| 1000 | 0.011% | 0.01% |
| 500 | 0.006 | 0.01 |
| 300 | 0.004 | 0.01 |
| 200 | 0.003 | 0.01 |
| 100 | 0.002 | 0.01 |
| 50 | 0.002 | 0.01 |
| 30 | 0.001 | 0.01 |
| 20 | 0.001 | 0.01 |

## 1.6 DANA AMPLIFIER ENCLOSURES

The Model 2616 Enclosure (Figure 1.3) holds sixteen 2615 amplifiers and a shared power supply. The dimensions of the enclosure are: depth, 15 inches; width, 19 inches; height, 3.5 inches. The basic model number is modified by a dash number which specifies the type of input/output connectors.

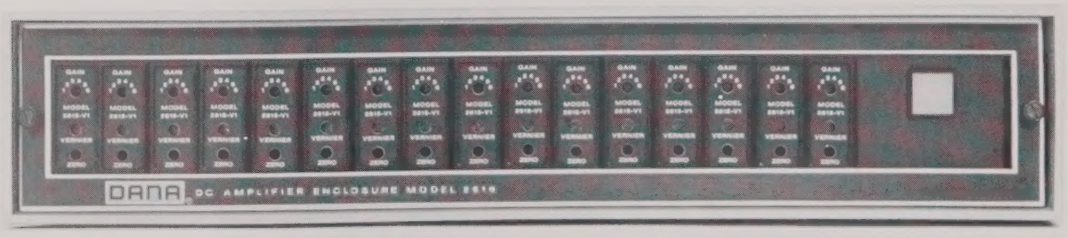


Figure 1.3 - Model 2616 Enclosure

The -1 series contains printed circuit connectors to accommodate system wiring. Fusing and AC wiring, are factory installed (Drawing 402561, Section 6). Series -2 enclosures are fully wired for single-output amplifiers. Two 50 pin connectors are mounted on the back plate (Drawing 402726). Mating connectors are supplied.

Wiring instructions for each type enclosure are included in Section 2, "Installation".

# SECTION 2

# INSTALLATION

## 2.1 UNPACKING AND INSPECTION

The 2600 Series Amplifier is shipped in the 2616 enclosure. The enclosure is placed between two forms of plastic foam and packed in a double-walled cardboard carton for shipment. This packaging is designed to absorb shocks encountered in transit. Prior to unpacking examine the exterior of the shipping carton for signs of damage. Carefully remove the rack and inspect for any visable signs of damage. If damage is found, notify the carrier immediately.

## 2. 2 POWER REQUIREMENTS

Power for the 2600 Series amplifiers is provided by a shared power supply located on the right side of the 2616 enclosure. The power supply operates on 115 volts $\pm$10%, 50 to 400 Hz. Export units operate on 210 to 250 volts, 50 to 400 Hz. Power required is 2.5 watts for each amplifier.

> NOTE
>
> If the Amplifier has been stored for a prolonged period (5 or 6 months) without use, it is recommended that it be operated with a variable transformer, such as a Variac, at one-half line voltage for about two hours before gradually applying full power. This is done to "reform" the electrolytic capacitors in the amplifier and reduce the chance of capacitor failure.

## 2.3 INPUT-OUTPUT CONNECTIONS

### 2.3.1 General

Inputs and outputs to the amplifier are through a 15-pin printed circuit connector at the rear of the amplifier. The mating connector for the amplifiers is mounted on the inside back panel of the enclosure; each amplifier plugs into its corresponding connector.

When the 2616-1 enclosure is used, external connections are made directly to the solder side of the enclosure mounted connector for each amplifier. Access to connectors is gained by removing the top cover of the enclosure. External leads are routed through two openings on the rear of the enclosure.

In 2616-2 enclosures, 50 pin connectors are mounted on the rear panel. Connections are made by wiring to the mating connector. All pin connections are identified in the Enclosure Drawings (402561 or 402726).

### 2.3.2 Power

The power input connector for the 2616-1 and the 2616-2 is prewired and a three-wire line cord is supplied.

### 2.3.3 Input/Output Signals

For permanent installations, low thermal solder (70% cadmium, 30% tin) must be used for all input connections. For temporary or test setups, screw terminals or clips having low resistance may be used, taking suitable care to minimize thermal emf's (a few microvolts can be significant on high gain ranges).

Since the P and N inputs to the amplifier are symmetrical (approximately equal impedance to output common), either lead may be connected to either side of the signal source. For phasing purposes, if P is positive with respect to N, the output is positive with respect to output common.

Input leads should be two-conductor enclosed in an insulated shielded cable. The shield must be soldered to the guard pin connection (pin M when a -1 type enclosure is used; pin assignments are shown in 402726 for a -2 type enclosure). The unshielded portion of the leads must be kept as short as possible.

A single conductor shielded cable is recommended for output leads. Output commons from each amplifier and the power supply common should be joined at a common point. Return leads from the amplifier loads should also be connected to this point.

## 2.4 INITIAL CHECKOUT PROCEDURES

The amplifier is accurately adjusted and carefully inspected at the factory. The following tests check basic characteristics of the amplifier to verify proper operation upon delivery. The type of damage that can be expected in shipment tends to produce gross malfunctions rather than minor changes in sensitive characteristics. More complete and precise tests and calibration procedures are included in Section 5, "Calibration and Maintenance."

Only three items of test equipment are required to perform initial checkout of the amplifier:

Audio Oscillator
Voltage Divider/Attenuator
Oscilloscope

Standard laboratory-type instruments from any manufacturer may be used.

2.4.1 Gain Checkout

(a) Connect the common or ground terminals of each item of test equipment to a single point and to the amplifier output common (F). Connect this point to ground. Make all measurements relative to this point (see Figure 2.1).

(b) Set voltage divider to minimum output — zero, if possible.

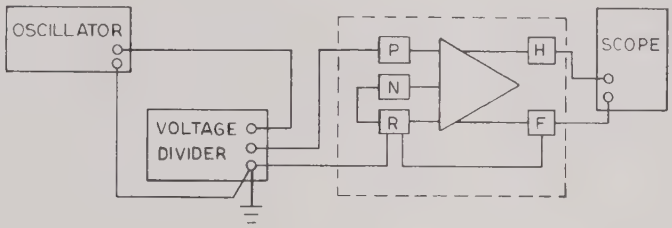


Figure 2.1 - Gain Test Setup

(c) Apply power to amplifier. Observe amplifier output on oscilloscope. It should be within a few millivolts of ground and change only very slightly as the amplifier GAIN switch is rotated.

(d) If the amplifier is equipped with a V1 option, set the VERNIER gain adjustment fully counterclockwise.

(e) Set the GAIN selector switch at the highest gain position.

(f) Remove scope lead from amplifier output and connect scope to the oscillator output. Adjust oscillator for 20 volts, peak to peak, at 100 Hz.

(g) Set voltage divider to the reciprocal of the maximum gain setting, 1/K. (For example, at maximum gain of 1000, set divider to .001.)

(h) Return the scope to the amplifier output, pin H. The scope should now indicate approximately the same value, 20 volts peak to peak, observed at the oscillator output. (The term "approximately" is used because of the limited capability of an oscilloscope to compare two magnitudes accurately.)

(i) Verify that there is no obvious noise or other unexplained distortions on the oscilloscope trace.

2.4.2 Frequency Response Checkout

(a) Use test setup exactly as connected for Gain checkout. Set amplifier GAIN control at maximum; vernier adjustment to minimum. Connect scope to oscillator output; set oscillator frequency to 20 kc.

(b) Set oscillator output at 20 volts, peak to peak (on scope).

(c) Remove scope lead from oscillator and connect to amplifier output pin H. Adjust voltage divider for amplifier output amplitude equal to that observed in step b.

(d) Compare voltage divider setting with zero — or minimum output position. The difference should be no more than ±1 dB, or approximately 10%.

2.4.3 Common Mode Rejection

(a) Short the amplifier input leads and the input guard lead (pins P, N, R). Connect all three to oscillator output.

(b) Connect oscilloscope to amplifier output pin H.

(c) Set oscillator output to 20 volts, peak to peak, at 60 Hz.

(d) Set amplifier GAIN switch to 1000.

(e) Observe amplifier output on scope. The output due to common mode is normally not detectable above the wideband noise of the amplifier. Common mode rejection can be calculated as follows:

$$CMR = \frac{20 \text{ Volts (P-P)} \times K}{\text{Output Voltage (P-P)}}$$

Common mode rejection may be measured more closely by following the procedures of paragraph 5.3.1, Section 5.

# SECTION 3

# OPERATION

## 3.1 MODES OF OPERATION

The Dana Amplifier can be used in any of the four operating modes illustrated below.

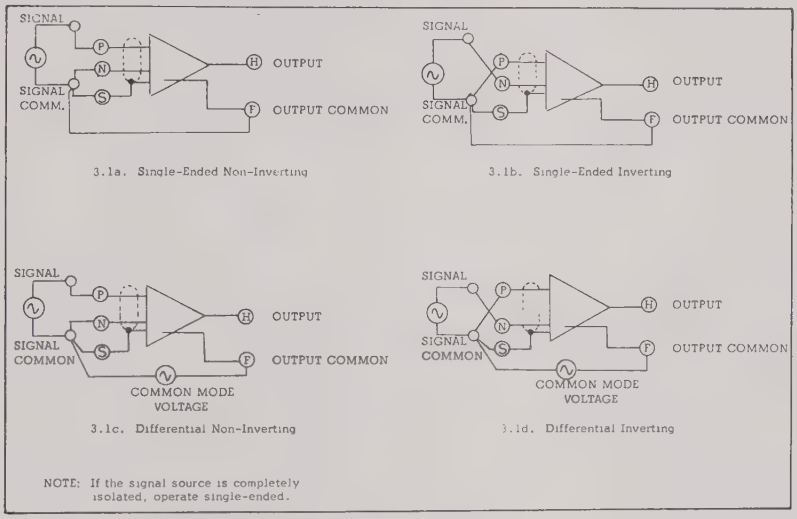


Figure 3.1 - Modes of Operation

## 3.2 CONTROLS

### 3.2.1 GAIN Selector Switch

The GAIN switch is rotated to select the desired gain of the amplifier. The gains which can be selected vary with the options specified. Gain positions are tabulated below.

| Options | GAIN Switch Positions |
|---|---|
| V1 | 20, 50, 100, 200, 500, and 1000 |
| V3 | 100, 200, 500, 1000, 2000, and 5000 |

## 3.3 OPERATIONAL ADJUSTMENTS

### 3.3.1 ZERO Adjustment

ZERO is a screwdriver adjustment on the front panel of the amplifier. It is used to set the output voltage to zero volts with no input. It is adjusted in the following manner:

(a) Apply power to the amplifier and any adjoining heat-producing equipment and allow amplifier to stabilize (approximately 30 minutes).

(b) Set GAIN selector switch to lowest gain position.

(c) Return the input P and N leads to output common (pin F).

(d) Connect voltmeter or scope to amplifier output pins H and F.

(e) Adjust ZERO for zero amplifier output.

### 3.3.2 GAIN Adjustment

This is a screwdriver adjustment which serves as a vernier adjustment of gain selected by the GAIN selector switch. With V1 and V3 options, the adjustment varies each gain position by a factor of +2.5 — providing continuous gain selection throughout all available ranges.

## 3.4 OPERATING PROCEDURES

After installation of the amplifier as described in Section2, operation consists simply of selecting the appropriate gain. The amplifier is ready for use immediately with zero stability achieved within 30 minutes.

# SECTION 4

# THEORY OF OPERATION

## 4.1 INTRODUCTION

A block diagram of the Model 2615 Dana Amplifier is shown in Figure 4.1. The forward loop consists of the normal mode amplifier and output amplifier. The loop is closed by the feedback circuit through an attenuator. The common mode amplifier provides feedback across the first stage of the normal mode amplifier.

Output voltage of the amplifier is proportional to the electrical difference between the two input terminals, with potentials common to both inputs being rejected. Normal mode signals (also referred to as "difference" or "differential" signals) and common mode signals are defined below.

$$\text{Normal Mode Signal} = E_1 - E_2$$

$$\text{Common Mode Signal} = \frac{E_1 + E_2}{2} \text{ (mid point between } E_1 \text{ and } E_2)$$

Figure 4.2 shows the amplifier responding to normal mode signals and rejecting the common component (one-half of the bridge supply voltage). In practical applications, there would be additional common potentials due to stray fields and other causes. These potentials represented by "$E_x$" are also rejected.

## 4.2 NORMAL MODE AMPLIFIER

The input stages, insofar as normal mode signals are concerned, are similar to conventional balanced differential circuits currently in common use, e.g., differential oscilloscope preamplifiers. Input lines are connected to the base of a pair of matched silicon transistors (dual transistors in a single case) and circuit parameters are adjusted to obtain equal characteristics in each stage. A unique aspect of the circuit is the technique employed in controlling these parameters for stable operation over wide temperature ranges.

The outputs of the balanced differential stages are combined in a summing circuit which transfers one directly and inverts the other, thus the differential response characteristic of $E_1 - E_2$. Signals of common polarity or phase will cancel at the summing stage, the degree of cancellation dependent on their relative magnitudes.

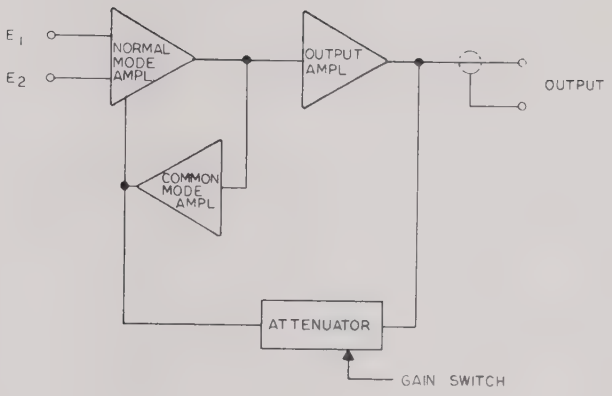


Figure 4.1 - Block Diagram, Model 2615

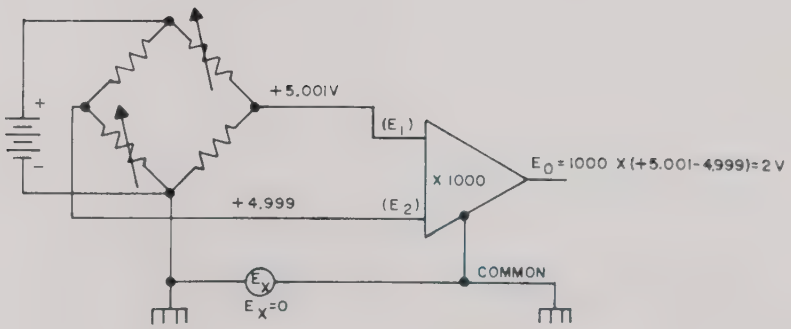


Figure 4.2 - Normal/Common Mode Response

Figure 4.3 is a simplified diagram of the input stages and summing circuit. For convenience, the diagram has shown equal and opposite input signals which add at the summing stage. Later in the text, it will be shown that the amplifier will always have this signal symmetry internally, regardless of the symmetry of the input signal.

To achieve the desired gain stability and linearity, the open look gain (gain without feedback) is considerably greater than the closed loop gain. By keeping this ratio sufficiently high, the "closed loop" or "net gain" is essentially determined by the feedback elements alone. Although the Dana amplifier has what might be termed a compound feedback network, it is similar in principle to the simplified circuit shown in Figure 4.4.

Examining this feedback system, it can be seen that the feedback is of the proper phase to cancel the effect of the input signal; however, the cancellation leaves a small "error" signal of sufficient magnitude to support the 5-volt output. In the example, if the open loop gain of the circuit were 140dB, the approximate residual error signal would be $5V/10^7$ or .5 μV ($E_e$ in the diagram).

This type of amplifier is a potentiometric device, since the feedback achieves a high effective input impedance by the same principle as the common "battery potentiometer" approach to precision measurements. In both cases, the effective input impedance approaches infinity at null. In the potentiometric amplifier, impedance is limited by factors such as leakage and practical values of loop gain.

The actual circuit differs from the above example in that a more complex system of feedback is required for the differential amplifier involving the Common Mode Amplifier which is described next.

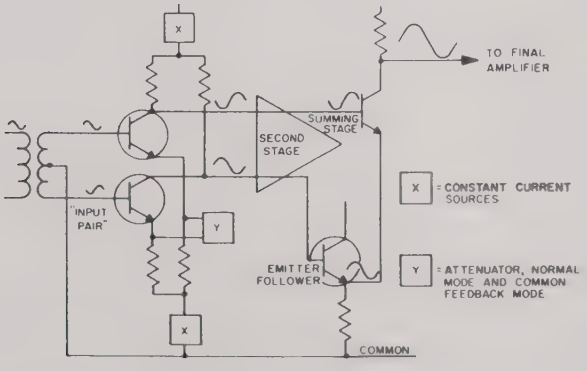


Figure 4.3 - Simplified Normal Mode Amplifier

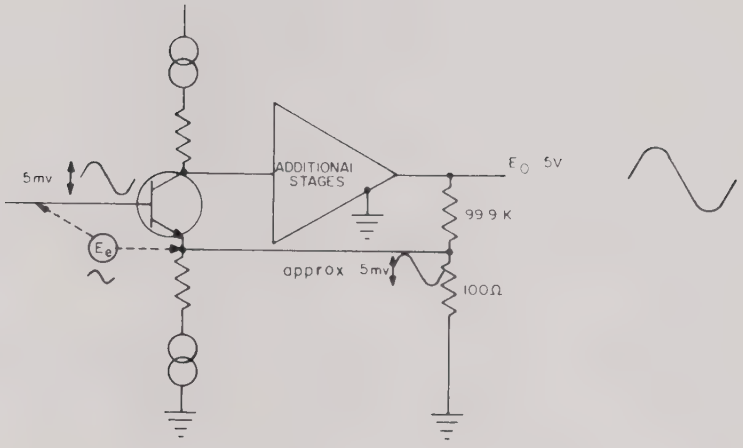


Figure 4.4 - A Simplified Potentiometric Amplifier
(Gain of 1000)

## 4.3 COMMON MODE AMPLIFIER

Although the Normal Mode Amplifier provides a degree of common mode rejection (CMR = 60 to 70 dB with balanced source), it is insufficient for high accuracy data systems. The primary deficiency of this circuit is the low impedance between the input lines and common — too low to materially reduce common mode currents. This deficiency is overcome by the use of a separate Common Mode Amplifier (CMA) which senses the common mode voltage at the input and forces the emitters of the "input pair" of the Normal Mode Amplifier to the same potential (neglecting bias). This "bucking" voltage allows very little current to flow from either input lead to output common, increasing the intrinsic impedance to common. As in any potentiometric amplifier, practical loop gain values and other factors preclude infinite impedance; however, typical Dana Amplifiers exceed 350 megohms. The action of the CMA is shown in simplified form in Figure 4.5. Transistors are the "input pair" of the Normal Mode Amplifier.

Reviewing the action of the Normal Mode Amplifier, differential input signals cause out-of-phase signals to be developed across the input pair's respective collector resistors. Under these conditions, the drop across the collector summing resistor (R1 in Figure 4.6a) remains constant; however, a voltage source common to both input lines causes in-phase collector current variations which add through R1 and produce a signal proportional to the common mode potential, providing an input to the CMA. As illustrated in Figure 4.6, the CMA couples a feedback signal to the emitters of the input pair through R5(s). This signal is of the proper phase to cancel the effect of the input potential and maintain the sum of the two collector currents constant. Cancellation is complete except for a small residual error voltage necessary to maintain the output of the CMA very near the common mode potential (ignoring attenuator insertion loss).

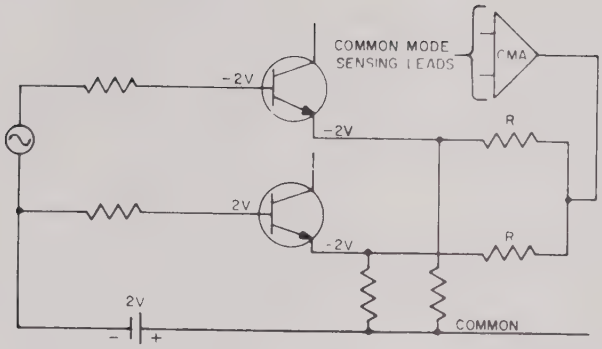


Figure 4.5 - Operation of the Common Mode Amplifier

For convenience, the Common Mode Amplifier has been described as if it were a single-ended device referenced to ground. However, the CMA is a differential amplifier much like the Normal Mode Amplifier and, as such, responds to the difference between its input terminals. In the actual circuit, one of the CMA input terminals is connected to the lower side of the input stage collector summing resistor and the other to a passive divider connected between the input pair emitters and the top of the collector summing resistor (Figure 4.6a).

If this circuit is closely examined, it can be seen that the various circuit elements form a simple bridge. This identify is established in Figure 4.6b. In operation, the application of a common potential to the input transistors tends to unbalance the bridge by changing the conductance of the input pair. This effect is opposed by driving the lower end of the bridge (or the emitters of the input pair) with the output of the CMA. This feedback effectively cancels the change in conductance and restores the bridge to balance.

As previously stated, the parameters of the input stage are carefully adjusted for nearly identical characteristics. Once established, they cannot be allowed to change when the circuit is subjected to common mode potentials. From Figure 4.6 it can be seen that the entire input circuit is floating between two constant current generators. Since it has been established that the active elements in the bridge circuit (transistors) are continuously balanced against passive elements (R1, R3, R4), it becomes apparent that the constant current sources will also serve to maintain constant voltage conditions across the bridge (constant I x constant R = constant E). This means that, as the lower part of the bridge is driven up and down asynchronously with common mode potentials, the voltage at the top of the bridge varies with the same relative magnitude. This "bootstrapping" effect raises the intrinsic common mode rejection of the input pair to the high values required for high accuracy systems.

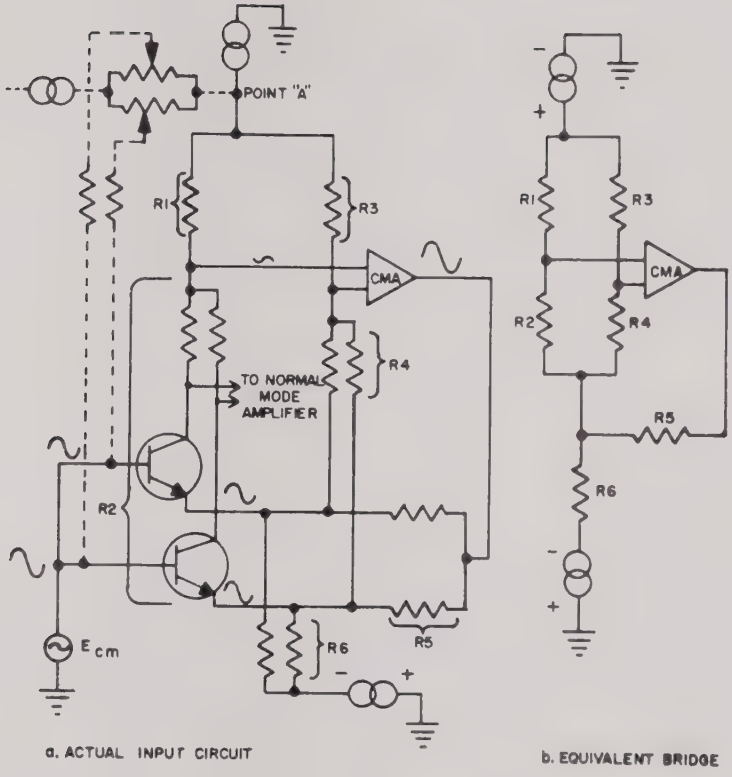


Figure 4.6 - The Common Mode Bridge

## 4.4 FEEDBACK CIRCUIT

The differential input of the amplifier requires a feedback network slightly more complex than the simple divider that was shown in Figure 4.4. To illustrate, consider the case where one input is connected to a positive signal and the other to a negative signal. It would appear that the proper bipolar feedback for both inputs could not be derived from a single output terminal; however, this is not the case.

Figure 4.7 shows the actual feedback network of the amplifier. For the purpose of the initial discussion, assume no connection between points A and B, and that the amplifier has somehow arrived at the proper ten-volt output for a ten-millivolt input (gain of 1000). It can be seen that the voltage difference between the two feedback lines is the required 10 millivolts; however, both lines are approximately +5 volts above common. This is obviously intolerable and the circuit will not function until a connection is made between

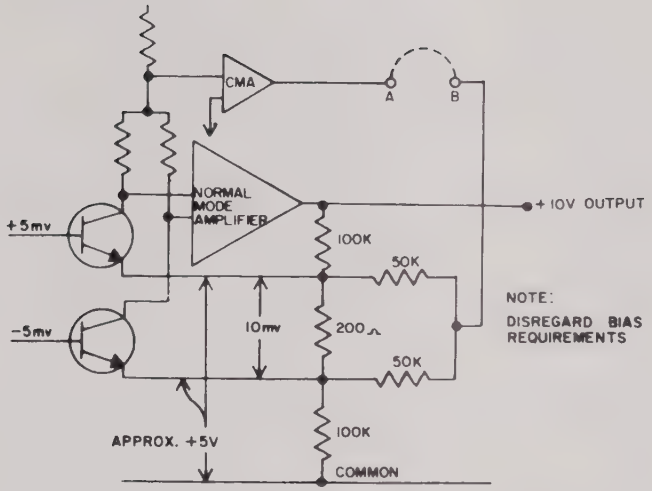


Figure 4.7 - Feedback Network for Gain of 1000

points A and B. It should be emphasized that the +5 volts is common to both input transistors and would tend to unbalance the common mode bridge just as an external common mode potential would do. The only difference in the two situations is the fact that the "feedback" common mode voltage is internally generated and tends to drive the input emitters in lieu of the bases. The latter results in one less phase inversion for internally generated common mode signals, producing an output from the CMA of the opposite output which goes negative until the feedback lines become approximately +5 millivolts and -5 millivolts with respect to common.

It can now be seen that the CMA will not tolerate the bridge to be unbalanced at any time, whether the common mode potential is introduced internally or externally. More specifically, the collector currents are never permitted to shift in the same direction but can only vary by equal and opposite amounts in response to differential input signals. This fact holds true regardless of the symmetry of the input signals. For example, consider the situation where one input is tied to common and the other is driven with a 10 millivolt AC signal. The CMA assumes the proper signal level so that equal and opposite error signals exist between the base and emitter of each input transistor. The final quiescent conditions are shown in Figure 4.8.

## 4.5 OUTPUT AMPLIFIER

The output amplifier consists of direct-coupled circuitry that amplifies the output of the normal mode amplifier and supplies the output voltage.

## 4.6 ADDITIONAL CIRCUIT DETAILS

For ease of explanation, several circuit details were intentionally overlooked. Specifically, the diagrams used to illustrate certain fundamental points inferred a quiescent voltage level of zero at several points that are normally several volts positive or negative with respect to ground. Circuit operation as described is fundamentally accurate except that signal levels are relative to the initial conditions. The static bias condition of the input pair is of particular interest since it is related to input current uncertainty. These stages are initially forward biased and, though the base idling currents are quite low, they would develop an offset voltage if allowed to flow through the external signal source resistance.

To minimize this effect, each input line is connected to a source that shunts this current to the amplifier's internal supplies. An adjustment is provided for each input line, permitting the input current to be periodically rezeroed in the field (shown in dotted lines of Figure 4.6). To prevent common mode loading, these sources are floated between a constant current generator and the top of the common mode bridge. Since both input leads and the collector supply move together with the common mode potential, the current through the base resistors remains very nearly constant. This infers that the impedance to common potentials is a large magnification of the apparent 5 megohms in ecah base lead (on the order of 1000 megohms); and also points out that the quiescent base current is virtually undisturbed by common mode potentials.

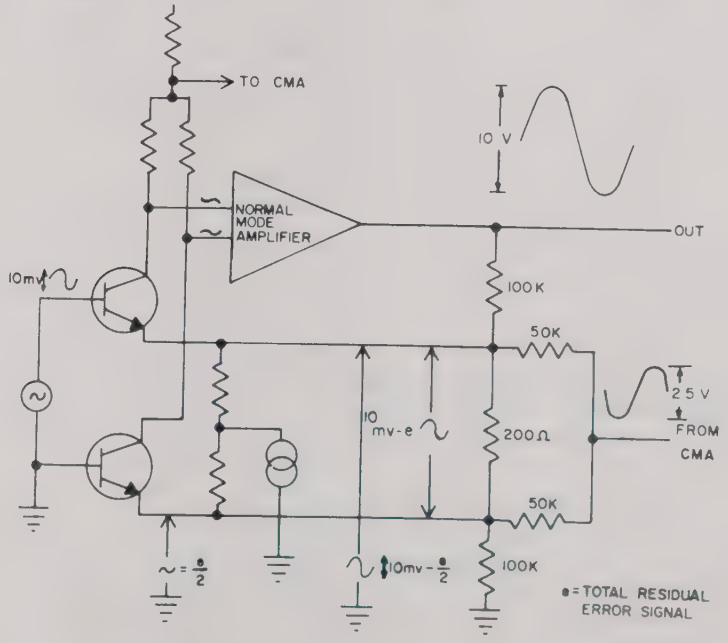


Figure 4.8 - Forced Internal Symmetry

# SECTION 5

# MAINTENANCE

## 5.1 TEST EQUIPMENT

(a) OSCILLOSCOPE - X-Y inputs; bandpass, DC - 500 kHz; calibrated deflection factors of 1 millivolt to 20 volts per centimeter accurate within 3%; input impedance, 1 megohm paralleled by less than 50 pF.

(b) OSCILLATOR - Frequency range, 5 Hz - 500 kHz; accuracy, ±2%; frequency response, ±1 dB; adjustable output voltage, 160 milliwatts (10 volts) into 600 ohms rated load, 20 volts open circuit.

(c) VACUUM TUBE VOLTMETER - Voltage range, 0.1 millivolt to 300 volts; dB range, -72 to +52 dB; frequency range, 10 Hz to 1 MHz accurate within ±2% (50 Hz - 500 kHz); input impedance, 10 megohms paralleled by less than 50 pF.

(d) ATTENUATOR - Attenuation to 120 dB in 1 dB steps; DC to 1 MHz accurate within ±1 dB; power capacity, 5 watts.

(e) DC MILLIVOLTMETER (Optional)

(f) Dana Model 2095 Test Panel (Optional) or Dana Cord Set (400227).
The Dana Model 2095 Amplifier Test Panel provides a convenient means of testing and calibrating Dana amplifiers. The panel requires that only the amplifier input, output and power inputs be connected with no further reconnections required. All input and output configurations necessary to calibrate of test the amplifier are set up by switches and controls mounted on the panel. The panel is shown in Figure 5.1.

A special adapter for 2615 to 2095 is used. Also a special 2095 panel with internal DC supply is needed.

## 5.2 LISSAJOUS FIGURES FOR COMMON MODE ADJUSTMENTS

The output null of the amplifier is checked with the Lissajous figures shown in Figure 5.2. The adjustments for the quadrature error and amplitude error are mentioned in paragraph 5.3.1. Figure 5.2a shows the amplifier output at null for maximum common mode rejection.

Oscillator 20 volts (P-P) at 60 Hz and amplifier GAIN at 10.

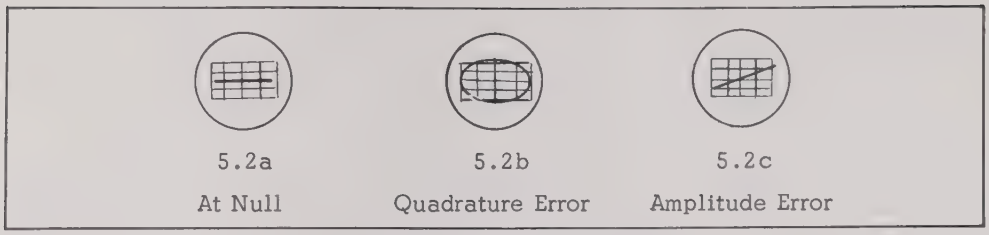


Figure 5.2 - Lissajous Figures

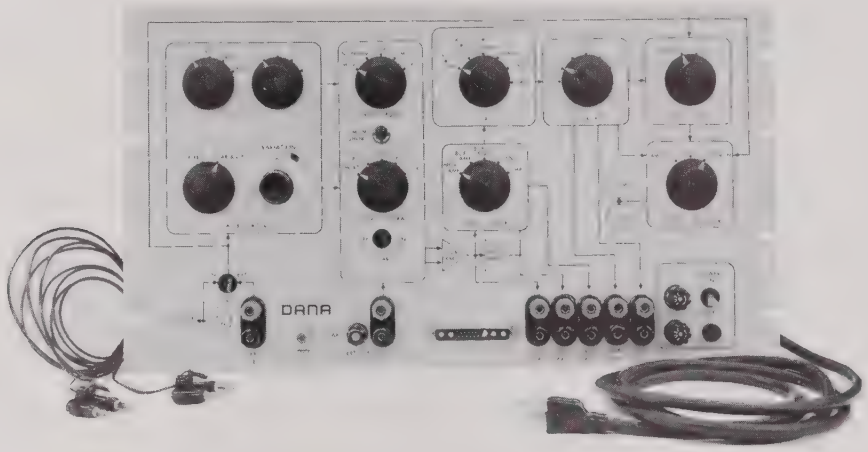


Figure 5.1 - Dana Model 2095 Amplifier Test Panel

## 5.3 CALIBRATION PROCEDURES

In addition to the following calibration procedures, certain performance characteristics should be checked periodically and internal adjustments made as required. These measurements are described in Section 5.4. The procedure below should be performed in the order listed.

### 5.3.1 Common Mode Adjustment

The amplifier has two controls that affect common mode rejection by adjusting the symmetry of the input circuit. R39 compensates for resistive unbalance and C7 adjusts the capacitive symmetry. The location of R39 and C7 is shown on drawing 402722, page 3 of 4, Section 6.

(a) Connect both inputs N and P and guard to the high side of a signal generator, returning the low side to wideband output common F.

(b) Connect the signal generator to the X axis of an oscilloscope with the X sensitivity set to 5 volts/cm.

(c) Connect amplifier output H to the Y axis of the oscilloscope through a single pole, low pass filter consisting of a 16K resistor and a .01 microfarad capacitor.

(d) Set the oscillator to 20 volts (P-P) at 60 cps and amplifier GAIN to 1000.

(e) Adjust R39 and C7 for minimum vertical deflection.

5.3.2 Collector Zero Adjustment

In addition to the operational ZERO adjustment on the front panel, the amplifier is equipped with a internal zero adjustment (R27) accessible through a small hole at the top of the Amplifier (see Section 6). Procedure for making this adjustment is as follows:

(a) Connect amplifier inputs N and P to output common F and guard.

(b) Connect an oscilloscope or millivoltmeter to output pins H and F.

(c) Set the amplifier GAIN switch to the lowest gain position; adjust the front-panel ZERO adjustment (R33) for minimum reading on the millivoltmeter. Record any residual offset.

(d) Set amplifier GAIN switch to highest gain position; adjust the internal collector ZERO adjustment (R27) for the same offset recorded in step c.

(e) Repeat steps c and d until the output remains the same on both the highest and lowest gain positions.

5.3.3 Input Current Adjustment

This adjustment minimizes current flow through the input terminals. For most accurate adjustment, the following procedures should be performed after the Collector Zero adjustment.

(a) Set amplifier GAIN switch to maximum gain position.

(b) Connect input terminals N and P to output common F and guard.

(c) Connect oscilloscope to output terminals H and F. Set vertical deflection to 5mV/cm. Record amplitude of offset voltage at output.

(d) Disconnect N terminal from output common; insert 1K resistor in series and reconnect to output common and guard.

(e) Adjust R10, the N current control, for same offset recorded in step c.

(f) Remove 1K resistor from N lead and reconnect N lead to output common and guard. Remove P lead, insert 1K resistor in series, and reconnect to output common and guard.

(g) Adjust R9, the P current control, for same offset recorded in step c.

(h) Repeat steps d through g until offset is exactly the same in each step.

5.3.4 Output Zero Adjustment

This adjustment sets the zero of the Output Amplifier by means of the ZERO adjustment on the front panel.

(a) Connect input terminals N and P to output common terminals F and J. Connect this point to ground.

(b) Connect an oscilloscope across the wideband output, terminals F and H.

(c) Vary the ZERO adjustment (on front panel) for minimum reading on oscilloscope. Note this voltage for further reference. (This voltage represents residual offset.)

5.4 TESTS OF AMPLIFIER CHARACTERISTICS

The following measurements check basic amplifier operating characteristics — such as gain, bandpass, etc.

5.4.1 DC Gain Measurement

(a) Connect test setup as shown in Figure 5.3. (The signal source need not be particularly accurate or stable, but the voltage divider must be extremely accurate. The null detector must be isolated and resolve less than 1 mV.

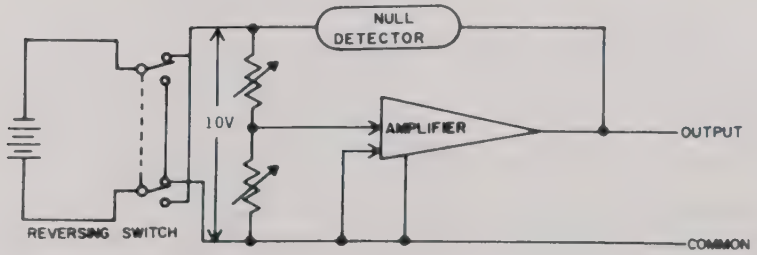


Figure 5.3 - Test Setup - DC Gain Measurement

(b) Set DC voltage source at 10 volts.

(c) Adjust voltage divider so that there is no change in null detector indication when the input polarity is reversed by the reversing switch. Note ratio of voltage divider setting. Calculate gain as follows:

$$K = \frac{1}{h}$$

where K = amplifier gain
h = ratio of voltage output to input of divider.

5.4.2 Linearity Measurement

Ideally, gain should be independent of the magnitude of the output voltage from minus full scale to plus full scale. Since the Dana Amplifier's departure from this idea is small, the null balance method of the gain measurement is again used. Linearity can be measured immediately after the DC gain measurement (see Figure 5.3). The test setup shall remain the same except that a variable DC voltage is required.

Steps 1 and 2 are followed as for DC Gain Measurement (5.4.1). The input voltage is then varied from minus full scale to plus full scale, and the peak reading of the null detector recorded. The linearity in percentage can be calculated as follows:

$$\frac{\text{Peak Null Detector Reading (Volts) X 100}}{\text{Full Scale (10 Volts)}}$$

5.4.3 AC Gain Measurement

The technique used for DC gain measurement can be extended to AC if the phase lag in the amplifier is compensated and a suitable null detector is used. If these types of measurements are anticipated, a special transformer and phase correction network may be procured from Dana; however, in general, a simpler and more direct method is described below:

(a) Connect test setup as shown in Figure 5.4. (The divider should be of sufficiently low impedance to prevent errors due to source resistance. The output meter should be a good quality AC voltmeter having a mirrored scale and at least 100 minor dividions — H/P 400H or equivalent.)

(b) Place the monitor switch to position 1 and set the signal generator to an output of approximately 7 volts RMS at 60 cps.

(c) Select a minor division on the meter's best scale (maximum resolution and legibility) and adjust the output of the signal generator very carefully to place the needle of the meter directly on this marker. Use the mirror to avoid parallax.

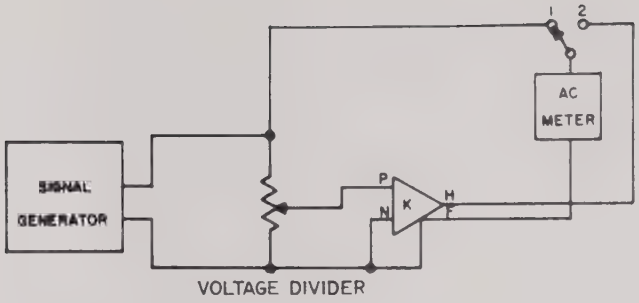


Figure 5.4 - Test Setup — AC Gain Measurement

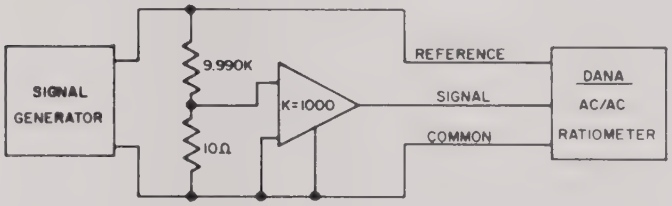


Figure 5.5 - Test Setup to Measure High Frequency Linearity

(d) Set the monitor switch to position 2 and adjust the voltage divider for exactly the same reading established in step b.

(e) Carefully observing the meter, move the monitor switch alternately between positions 1 and 2 to ensure that the reading is exactly the same in both positions.

(f) Compute the gain of the amplifier by taking the reciprocal of the ratio setup on the voltage divider.

5.4.4 Bandwidth Measurement

Bandwidth is measured by determining the difference in AC gain at low and at high frequencies. Since there is seldom a need to define bandwidth with extreme accuracy, the measurement procedures may be shortened as follows:

(a) Use same test setup as for AC Gain measurement, Figure 5.4.

(b) Follow steps a through d of AC Gain Measurement with the signal generator set to 60 cps.

(c) Increase the frequency to 20 kHz and record the difference in readings between switch positions 1 and 2. If the meter has 100 minor divisions, each division represents approximately 1.4% of full scale.

In making the above measurement, it must be remembered that the bandwidth specifications apply for source impedances up to 350 ohms. When checking bandwidth, make certain this value is not exceeded. If a low impedance divider is not available, it may be necessary to improvise one.

5.4.5 High Frequency Linearity

Linearity is determined by the following equation:

$$\text{Linearity (in \%)} = 100 \frac{E_{out} - KE_{in}}{E_{out} \text{ (full scale)}}$$

To measure high frequency linearity, an extremely accurate AC/AC ratiometer is required such as the Dana Model 5640. The measurement procedures are listed below:

(a) Connect test setup as shown in Figure 5.5. Set the signal generator approximately 7 volts RMS at 60 Hz. Set amplifier GAIN to 1000.

(b) Trim the input divider and/or the amplifier vernier control until the absolute ratio is .99990 (displayed on ratiometer as 9.9990). This reading indicates a slight gain error; however, this is not important to the linearity measurement and allows the latter to be made with greater resolution.

(c) Leaving all other adjustments set, increase the signal generator frequency to 2 kHz and observe the new reading on the ratiometer.

(d) Compute linearity as follows:

$$\text{Linearity in \%} = \frac{\text{Reading 1 - Reading 2}}{1000}$$

If no range changes are involved, the result can be more quickly computed by allowing .001% for each digit of difference.

# SECTION 6

# DRAWINGS

## 6.1 DRAWINGS

| | |
|---|---|
| PC Board Assembly - 2615 V1 | 402722 |
| Schematic - 2615 V1 | 430710 |
| Schematic - 2615 V3 | 430792 |
| Assembly - Power Supply | 402618 |
| Schematic - Power Supply | 430713 |
| Enclosure Assembly 2616-1 | 402561 |
| Enclosure Assembly 2616-2 | 402726 |

| REF DES | PART NO | DESCRIPTION |
|---|---|---|
| CR15 | 211083 | 018 |
| CR14 | 211083 | 018 |
| CR13 | 211083 | 018 |
| CR12 | 211083 | 018 |
| CR11 | 220022 | IN965B |
| CR10 | 220022 | IN965B |
| CR9 | 211083 | 018 |
| CR8 | 220030 | 1/4W2 4AZ5 |
| CR7 | 211083 | 018 |
| CR6 | 211083 | 018 |
| CR5 | 211083 | 018 |
| CR4 | 211083 | 018 |
| CR3 | 211083 | 018 |
| CR2 | 211083 | 018 |
| CR1 | 211083 | 018 |
| | | |
| | | |
| C16 | 100006 | 10pF |
| C15 | 101174 | 001UF |
| C14 | 111262 | 10UF 25V |
| C13 | 111262 | 10UF 25V |
| C12 | 101641 | 470pF |
| C11 | [illegible] | 470pF |
| C10 | 100019 | .002UF |
| C9 | 100006 | 10pF |
| C8 | 100009 | 5pF |
| C7 | 130004 | 2.8pF |
| C6 | [illegible] | [illegible] |
| C5 | 100019 | .002UF |
| C4 | 101174 | 001UF |
| C3 | 101174 | 001UF |
| C2 | 101174 | 001UF |
| C1 | 101174 | 001UF |

| REF DES | PART NO | DESCRIPTION |
|---|---|---|
| Q22 | 200035 | 014 |
| Q21 | 200011 | 009 |
| Q20 | 200035 | 014 |
| Q19 | 200043 | 2N3565 |
| Q18 | 200068 | 2N4250 |
| Q17 | 200043 | 2N3565 |
| Q16 | 200043 | 2N3565 |
| Q15 | 200043 | 2N3565 |
| Q14 | 200043 | 2N3565 |
| Q13 | 201285 | DUAL NPN |
| Q12 | 200043 | 2N3565 |
| Q11 | 200068 | 2N4250 |
| Q10 | 200044 | (MATCHED PR R) |
| Q9 | 200043 | 2N3565 |
| Q8 | 200044 | (MATCHED PAIR) |
| Q7 | 200043 | 2N3565 |
| Q6 | 402720 | DUAL NPN |
| Q5 | 200068 | 2N4250 |
| Q4 | 200068 | 2N4250 |
| Q3 | 200043 | 2N3565 |
| Q2 | 201084 | 2N1304 |
| Q1 | 200068 | 2N4250 |
| | | |
| | | |
| | | |
| L1 | 400315 | 90UH |
| | | |
| | | |
| | | |
| CR20 | 220011 | IN968B |
| CR19 | 211083 | 018 |
| CR18 | 211083 | 018 |
| CR17 | 220011 | IN968B |
| CR16 | 220030 | 1/4W2 4AZ5 |

| REF DES | PART NO | DESCRIPTION |
|---|---|---|
| R30 | 000104 | 10k |
| R29 | 402720 | FSV 48.7k NOM |
| R28 | 402720 | FSV 49.7k NOM |
| R27 | 040115 | 500 POT |
| R26 | 010060 | 10k RN60D |
| R25 | 010087 | 11.5k RN60D |
| R24 | 402720 | FSV |
| R23 | 402720 | 5k POT |
| R22 | 020466 | 840 1% |
| R21 | 020415 | 100k 1% |
| R20 | 020415 | 100k 1% |
| R19 | 020443 | 281 |
| R18 | 020442 | 573.7 05% |
| R17 | 020441 | 1.530k 05% |
| R16 | 020440 | 3.442k 05% |
| R15 | 020439 | 9.178k 05% |
| | | |
| R13 | 010079 | 7.5k RN60D |
| R12 | 020412 | 50k 1% |
| R11 | 020412 | 50k 1% |
| R10 | 040104 | 50k POT |
| R9 | 040104 | 50k POT |
| R8 | 010182 | 1.13MEG RN60D |
| R7 | 010182 | 1.13MEG RN60D |
| R6 | 000106 | 10MEG |
| R5 | 000101 | 100 |
| R4 | 020414 | 350 3% WW |
| R3 | 020414 | 350 3% WW |
| R2 | 000392 | 3.9k |
| R1 | 000392 | 3.9k |
| | | |
| | | |
| | | |
| | | |
| | | |

| REF DES | PART NO | DESCRIPTION |
|---|---|---|
| R64 | 001704 | 1.8k 1/2W |
| R63 | 001675 | 100 1/2W |
| R62 | 000100 | 10 |
| R61 | 001704 | 1.8k 1/2W |
| R60 | 000100 | 10 |
| R59 | 001675 | 100 1/2W |
| R58 | 402720 | FSV 1.05k NOM |
| R57 | 402720 | FSV 1.05k NOM |
| R56 | 000330 | 33 |
| R55 | 001695 | 200 1/2W |
| R54 | 000100 | 10 |
| R53 | 000100 | 10 |
| R52 | 001695 | 200 1/2W |
| R51 | 000621 | 620 |
| R50 | 000431 | 430 |
| R49 | 000104 | 100k |
| R48 | 001678 | 10k 1/2W |
| R47 | 000203 | 20k |
| R46 | 000384 | 360? |
| R45 | 010122 | 28.7k RN60D |
| R44 | 000104 | 100k |
| R43 | 000104 | 100k |
| R42 | 000104 | 100k |
| R41 | 000202 | 2k |
| R40 | 000273 | 27k |
| R39 | 040114 | 50 POT |
| R38 | 020411 | 10.455k 1% |
| R37 | 020411 | 10.455k 1% |
| R36 | 000103 | 10? |
| R35 | 000243 | 24k |
| R34 | 010122 | 28.7k RN60D |
| R33 | 040116 | 1k POT |
| R32 | 402720 | FSV 49.7k NOM |
| R31 | 402720 | FSV 49.7k NOM |

| REF DES | PART NO | DESCRIPTION |
|---|---|---|
| | | |
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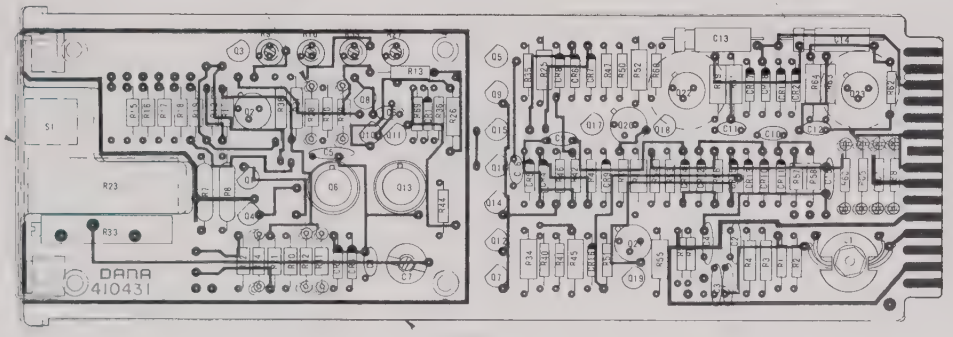



| | | | |
|---|---|---|---|
| | 2615 VI | 1 | 1 |
| NEXT DWG | USED ON | REQ'T DWG | FINAL ASSY |
| APPLICATION | | QTY REQD | |

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS: X .030, XX .020, XXX .010 | ANGLES: 0 30' FORMED 1 0' | HOLE DIAMETERS: ± .004, .001

MATERIAL

FINISH

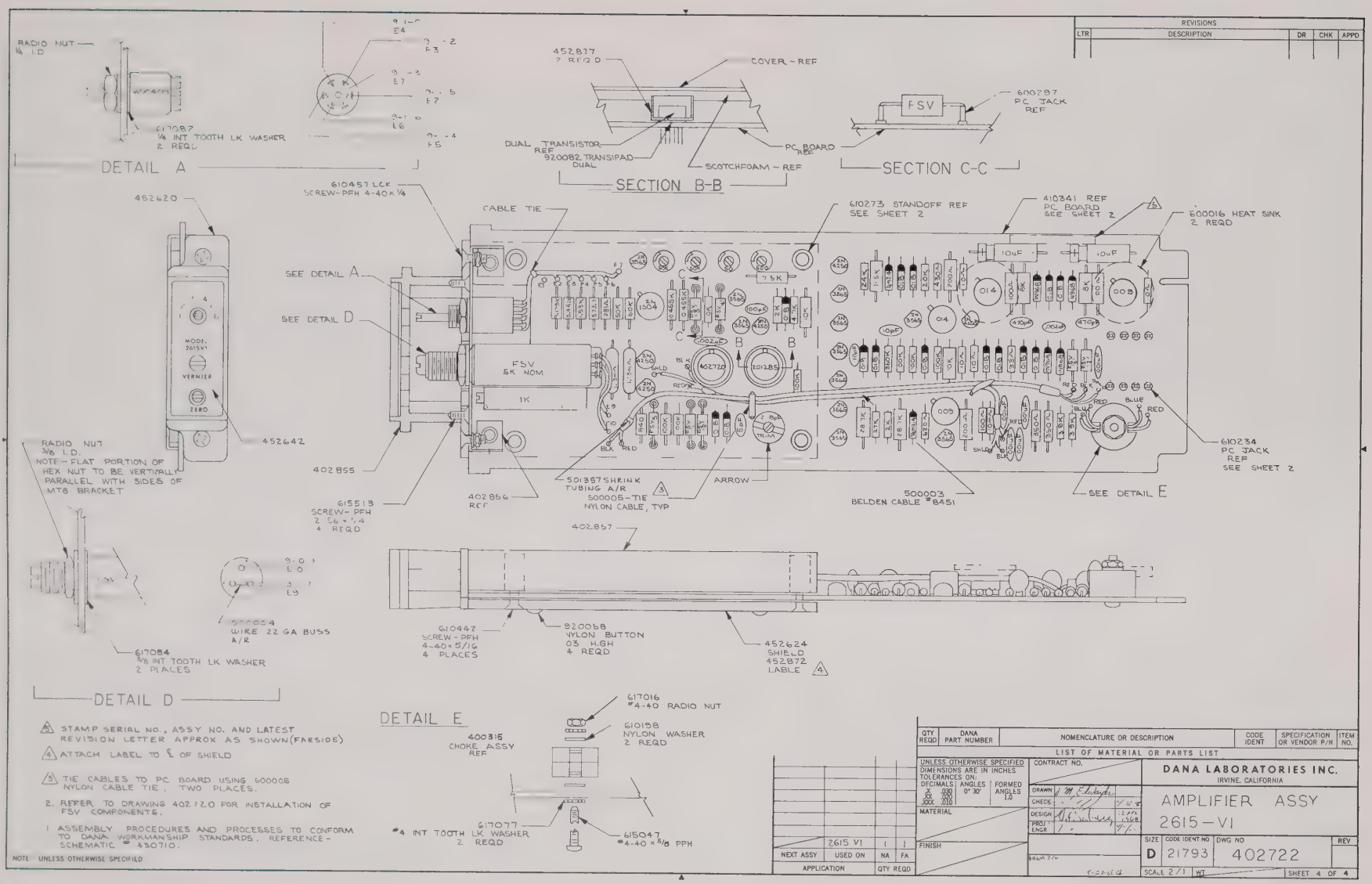
| | | |
|---|---|---|
| DRAWN | J. M. Richards | 4/4/68 |
| CHECK | | |
| DESIGN | | 4/68 |
| ENGR | | |
| PROJ ENGR | | |

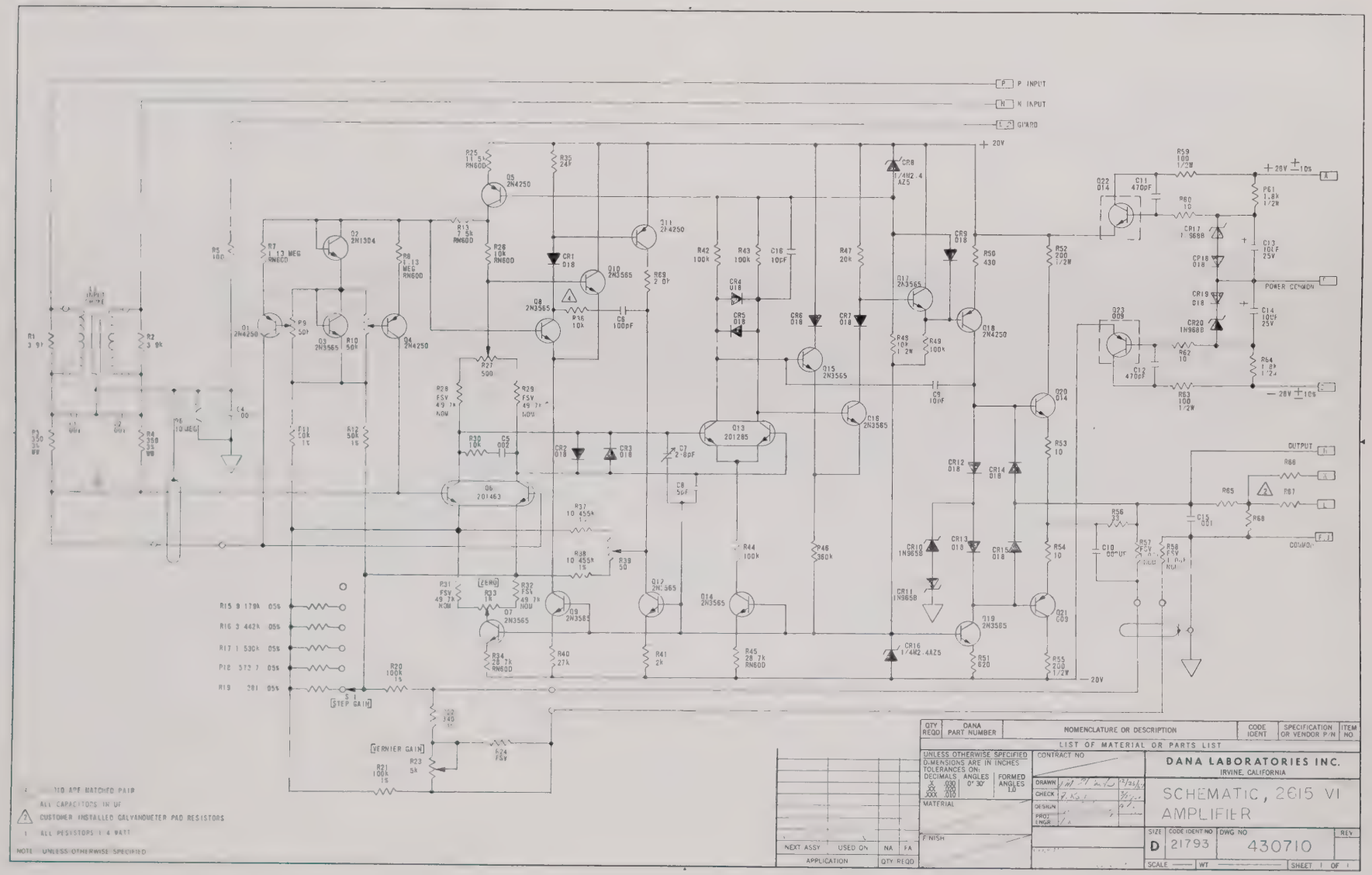
DANA LABORATORIES INC
IRVINE, CALIFORNIA

PC BOARD ASSY
MODEL 2615 VI

| SIZE | CODE IDENT NO | DWG NO | REV |
|---|---|---|---|
| D | 21793 | 402722 | |

SCALE 2 X 1 | SHEET 3 OF 4


REVISIONS
LTR
DESCRIPTION
DR
CHK
APPD
DETAIL A
SECTION B-B
SECTION C-C
DETAIL D
DETAIL E
452620
452642
402855
402856
402857
610457 LCK SCREW-PFH 4-40 X 1/4
CABLE TIE
SEE DETAIL A
SEE DETAIL D
FSV 6K NOM
1K
7.5K
610273 STANDOFF REF SEE SHEET 2
410341 REF PC BOARD SEE SHEET 2
600016 HEAT SINK 2 REQD
610234 PC JACK REF SEE SHEET 2
SEE DETAIL E
500003 BELDEN CABLE #8451
501387 SHRINK TUBING A/R
500005-TIE NYLON CABLE, TYP
ARROW
615513 SCREW-PFH 2-56 X 1/4 4 REQD
RADIO NUT 3/8 I.D.
NOTE - FLAT PORTION OF HEX NUT TO BE VERTICALLY PARALLEL WITH SIDES OF MTG BRACKET
617084 3/8 INT TOOTH LK WASHER 2 PLACES
617087 1/4 INT TOOTH LK WASHER 2 REQD
617074 WIRE 22 GA BUSS A/R
610442 SCREW-PFH 4-40 X 5/16 4 PLACES
920058 NYLON BUTTON 03 H.GH 4 REQD
452624 SHIELD 452872 LABLE
452877 2 REQD
COVER - REF
DUAL TRANSISTOR REF
920082 TRANSIPAD DUAL
PC BOARD REF
SCOTCHFOAM - REF
600297 PC JACK REF
617016 #4-40 RADIO NUT
610158 NYLON WASHER 2 REQD
400315 CHOKE ASSY REF
617077 #4 INT TOOTH LK WASHER 2 REQD
615047 #4-40 X 5/8 PPH
STAMP SERIAL NO., ASSY NO. AND LATEST REVISION LETTER APPROX AS SHOWN(FARSIDE)
ATTACH LABEL TO ℄ OF SHIELD
TIE CABLES TO PC BOARD USING 500005 NYLON CABLE TIE, TWO PLACES.
2. REFER TO DRAWING 402720 FOR INSTALLATION OF FSV COMPONENTS.
1. ASSEMBLY PROCEDURES AND PROCESSES TO CONFORM TO DANA WORKMANSHIP STANDARDS. REFERENCE - SCHEMATIC # 430710.
NOTE UNLESS OTHERWISE SPECIFIED
QTY REQD
DANA PART NUMBER
NOMENCLATURE OR DESCRIPTION
CODE IDENT
SPECIFICATION OR VENDOR P/N
ITEM NO.
LIST OF MATERIAL OR PARTS LIST
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
DECIMALS
ANGLES 0° 30'
FORMED ANGLES 1.0
CONTRACT NO.
DRAWN
CHECK
DESIGN
PROJ ENGR
MATERIAL
FINISH
DANA LABORATORIES INC.
IRVINE, CALIFORNIA
AMPLIFIER ASSY
2615-V1
SIZE
CODE IDENT NO
DWG NO
REV
D
21793
402722
SCALE 2/1
WT
SHEET 4 OF 4
2615 V1
NEXT ASSY
USED ON
NA
FA
APPLICATION
QTY REQD




1. 310 ARE MATCHED PAIR
2. ALL CAPACITORS IN UF
3. CUSTOMER INSTALLED GALVANOMETER PAD RESISTORS
4. ALL RESISTORS 1/4 WATT

NOTE: UNLESS OTHERWISE SPECIFIED

| QTY REQD | DANA PART NUMBER | NOMENCLATURE OR DESCRIPTION | CODE IDENT | SPECIFICATION OR VENDOR P/N | ITEM NO |
|---|---|---|---|---|---|

LIST OF MATERIAL OR PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
DECIMALS .XX ±.010 .XXX ±.005
ANGLES 0° 30'
FORMED ANGLES 1.0

MATERIAL

FINISH

CONTRACT NO

DRAWN
CHECK
DESIGN
PROJ ENGR

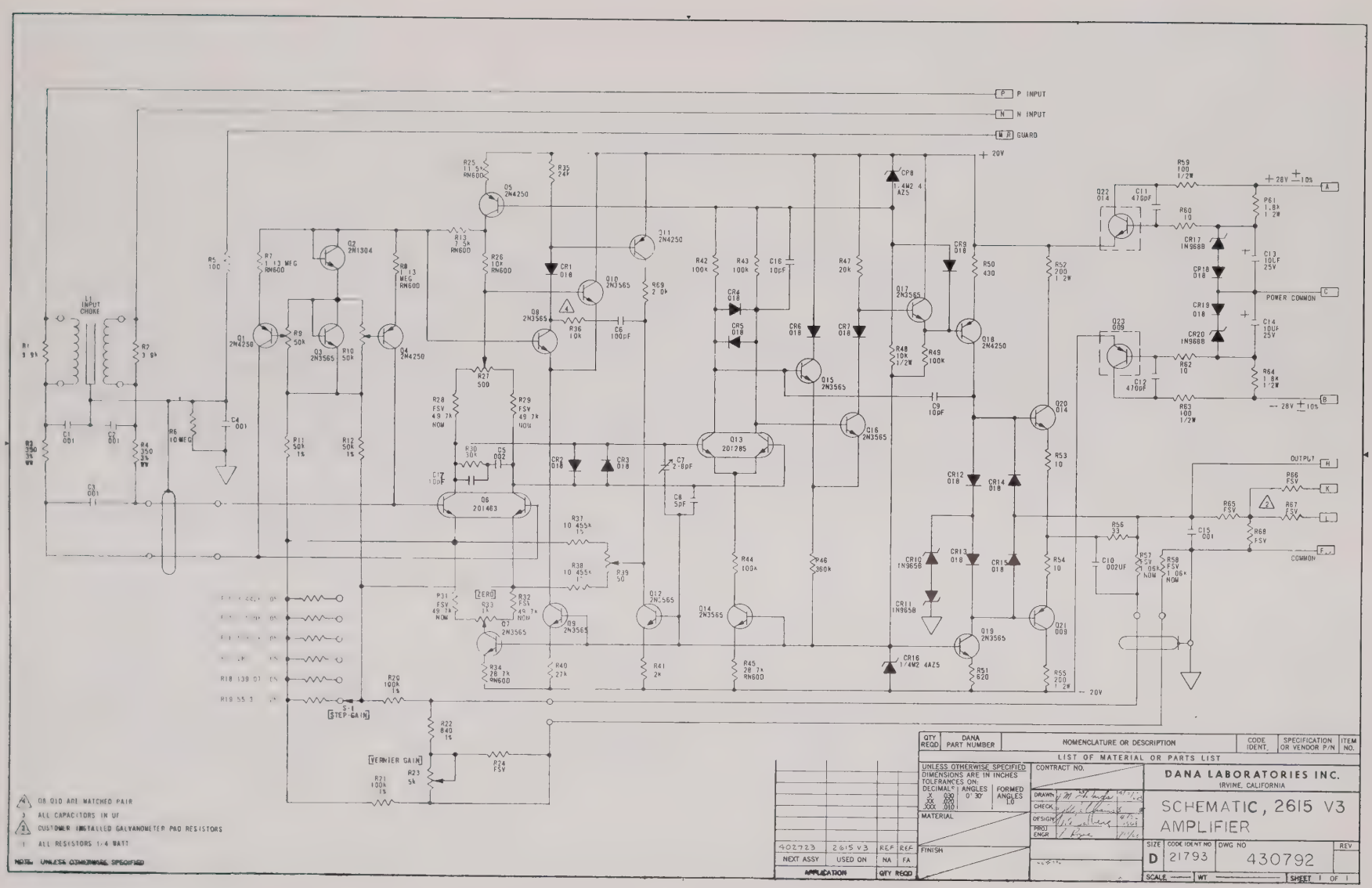
NEXT ASSY | USED ON | NA | FA
APPLICATION | QTY REQD

DANA LABORATORIES INC.
IRVINE, CALIFORNIA

SCHEMATIC, 2615 VI AMPLIFIER

| SIZE | CODE IDENT NO | DWG NO | REV |
|---|---|---|---|
| D | 21793 | 430710 | |

SCALE ——— WT ——— SHEET 1 OF 1




| QTY REQD | DANA PART NUMBER | NOMENCLATURE OR DESCRIPTION | CODE IDENT. | SPECIFICATION OR VENDOR P/N | ITEM NO. |
|---|---|---|---|---|---|

LIST OF MATERIAL OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON: DECIMALS ANGLES 0°30' FORMED ANGLES 1.0

MATERIAL

FINISH

CONTRACT NO.

DRAWN

CHECK

DESIGN

PROJ ENGR

| 402723 | 2615 V3 | REF | REF |
|---|---|---|---|
| NEXT ASSY | USED ON | NA | FA |
| APPLICATION | | QTY REQD | |

**DANA LABORATORIES INC.**
IRVINE, CALIFORNIA

# SCHEMATIC, 2615 V3 AMPLIFIER

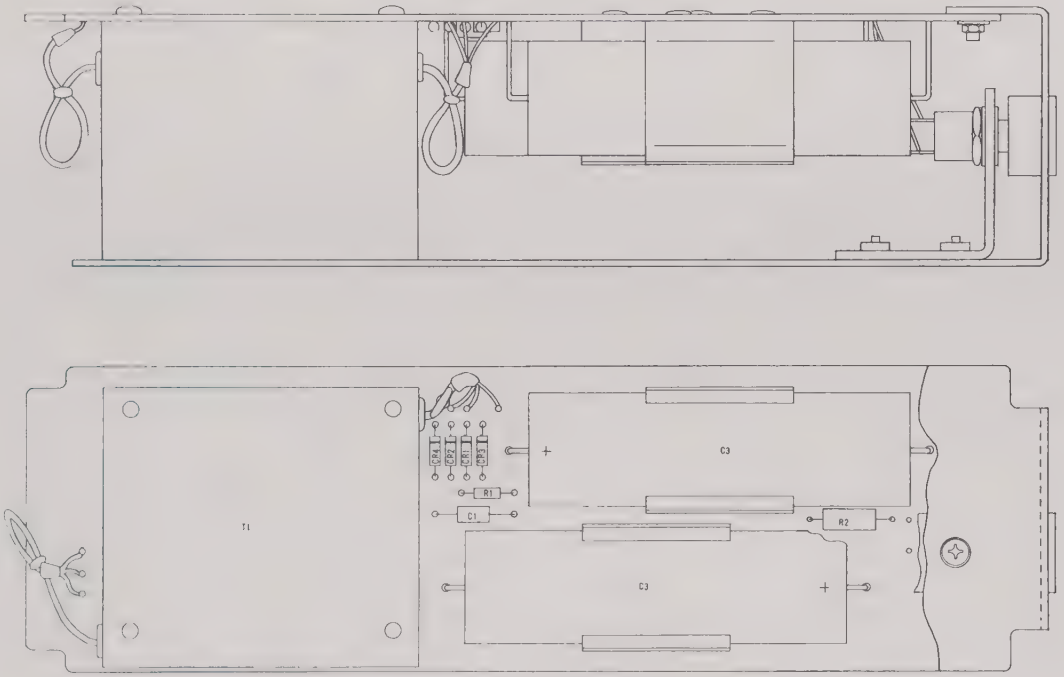
| SIZE | CODE IDENT NO | DWG NO | REV |
|---|---|---|---|
| D | 21793 | 430792 | |

SCALE — WT — SHEET 1 OF 1

(4) Q8 Q10 ARE MATCHED PAIR
(2) ALL CAPACITORS IN UF
(3) CUSTOMER INSTALLED GALVANOMETER PAD RESISTORS
(1) ALL RESISTORS 1/4 WATT

NOTE: UNLESS OTHERWISE SPECIFIED

| REVISIONS | | | | |
|---|---|---|---|---|
| LTR | DESCRIPTION | DR | CHK | APPD |
| | | | | |




| QTY REQD | DANA PART NUMBER | NOMENCLATURE OR DESCRIPTION | CODE IDENT | SPECIFICATION OR VENDOR P/N | ITEM NO |
|---|---|---|---|---|---|

LIST OF MATERIAL OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON DECIMALS: X .030, XX .020, XXX .010; ANGLES 0° 30'; FORMED ANGLES 1.0

MATERIAL

FINISH

CONTRACT NO.

DRAWN 2/21/62

CHECK

DESIGN

PROJ ENGR

DWG NO.

5-23-62-3

**DANA LABORATORIES INC.**
IRVINE, CALIFORNIA

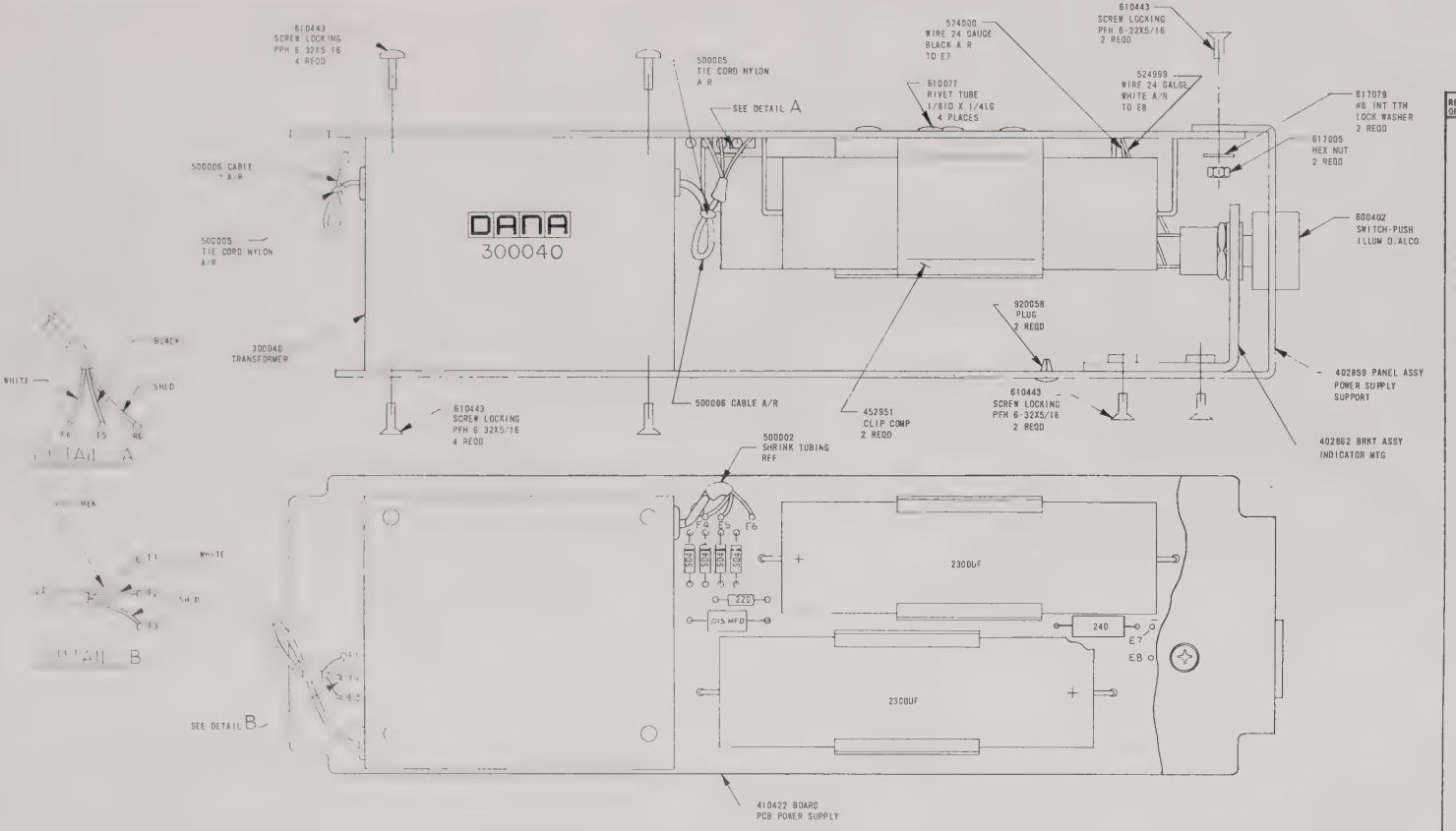
# POWER SUPPLY ASSEMBLY

| SIZE | CODE IDENT NO | DWG NO. | REV |
|---|---|---|---|
| D | 21793 | 402618 | |

SCALE 2 X 1 | WT | SHEET 1 OF 2

| NEXT ASSY | USED ON | NA | FA |
|---|---|---|---|
| | 7616 | 1 | 1 |
| APPLICATION | | QTY REQD | |

NOTE UNLESS OTHERWISE SPECIFIED




| REF DES OR ITEM | P/N | DESCRIPTION | QTY |
|---|---|---|---|
| C1 | 120131 | CAPACITOR .015UF 5% 100V MET MYLAR | 1 |
| C2 | 110081 | CAPACITOR 2300UF 50V EL SPRAGUE | 2 |
| C3 | 110081 | CAPACITOR 2300UF 50V EL SPRAGUE | REF |
| CR1 | 210004 | DIODE SD4 | 4 |
| CR2 | 210004 | DIODE SD4 | REF |
| CR3 | 210004 | DIODE SD4 | REF |
| CR4 | 210004 | DIODE SD4 | REF |
| R1 | 000221 | 220 OHM 1/4W | 1 |
| R2 | 001752 | 240 OHM 1W 5% | 1 |
| T1 | 300040 | TRANSFORMER | 1 |
| | 410422 | PCB PWR SUPPLY | 1 |
| | 420433 | ARTWORK | REF |
| | 430713 | SCREW | REF |
| | 402859 | PNL ASSY-PWR SUPL SUPPORT | 1 |
| | 402862 | BKT ASSY-INDICATOR MTG | 1 |
| | 452951 | CLIP COMP | 2 |
| | 500002 | SHRINK TUBING 153 ID | A/R |
| | 500005 | TIE CORD NYLON | A/R |
| | 500006 | CABLE STORW 824-19/38M-52V | A/R |
| | 524000 | WIRE-24GA STR 0 COLOR | A/R |
| | 524999 | WIRE-24GA STR 9 COLOR | A/R |
| | 600402 | SWITCH-PUSH ILLUM-DIALCO | 1 |
| | 610077 | RIVET 1/8 DIA X 1/4 LG SEMI-TUB | 4 |
| | 610443 | SCREW PPH 6-32 X 5/16 SELF LOCK | 12 |
| | 617005 | HEX NUT 6-32 STD STLS | 2 |
| | 617079 | WASHER INT LOCK 6 STLS | 2 |

| REF DES OR ITEM | P/N | DESCRIPTION | QTY |
|---|---|---|---|
| | 920010 | SOLDER 63/37 BAR | A/R |
| | 920026 | SOLDER WIRE 63263/37 RESIN CORE | A/R |
| | 920058 | PLUG PLASTEX 207-090241-00-0101 | 2 |
| | 920389 | LAMP-18V 04 AMPS NO 370 DIALCO | 1 |

| NEXT ASSY | USED ON | NA | FA |
|---|---|---|---|
| APPLICATION | 2616 | QTY REQD | 1 |

| QTY REQD | DANA PART NUMBER | NOMENCLATURE OR DESCRIPTION | CODE IDENT | SPECIFICATION OR VENDOR P/N | ITEM NO. |
|---|---|---|---|---|---|

LIST OF MATERIAL OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON: DECIMALS ANGLES X .030 0° 30' XX .020 XXX .010 FORMED ANGLES 1.0

MATERIAL

FINISH

CONTRACT NO.

DRAWN

CHECK

DES-GN

PROJ ENGR

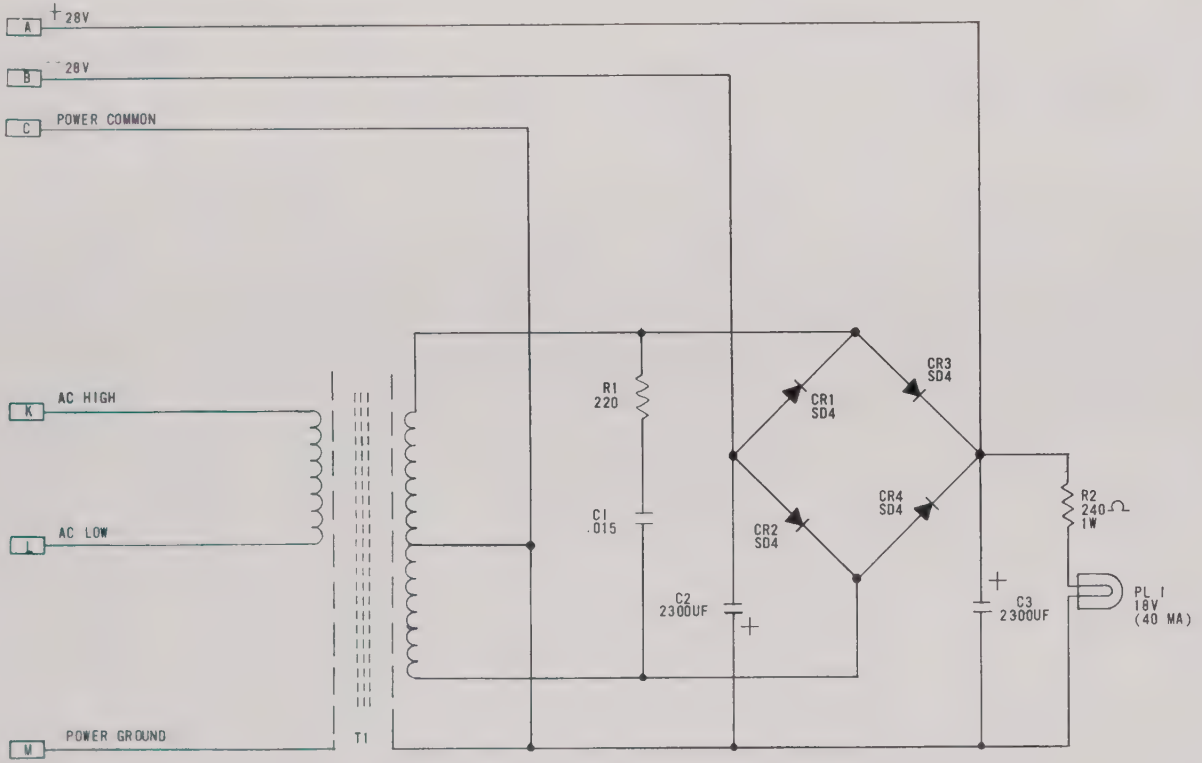
DANA LABORATORIES INC.
IRVINE, CALIFORNIA

POWER SUPPLY ASSEMBLY

| SIZE | CODE IDENT NO | DWG NO | REV |
|---|---|---|---|
| D | 21793 | 402618 | |

SCALE 2 X 1 WT SHEET 2 OF 2

NOTE UNLESS OTHERWISE SPECIFIED




| QTY REQD | DANA PART NUMBER | NOMENCLATURE OR DESCRIPTION | CODE IDENT | SPECIFICATION OR VENDOR P/N | ITEM NO. |
|---|---|---|---|---|---|

LIST OF MATERIAL OR PARTS LIST

| | | | |
|---|---|---|---|
| 402618 | 2616 | | |
| NEXT ASSY | USED ON | NA | FA |
| APPLICATION | | QTY REQD | |

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:

| DECIMALS | ANGLES | FORMED ANGLES |
|---|---|---|
| X .030 | 0° 30' | 1.0 |
| XX .020 | | |
| XXX .010 | | |

MATERIAL

FINISH

CONTRACT NO.

DRAWN J. M. Edwards 2/27/67
CHECK
DESIGN
PROJ ENGR 4/24/68
F. Rose 4/24/68
DANS 772

5-22-68 ✓

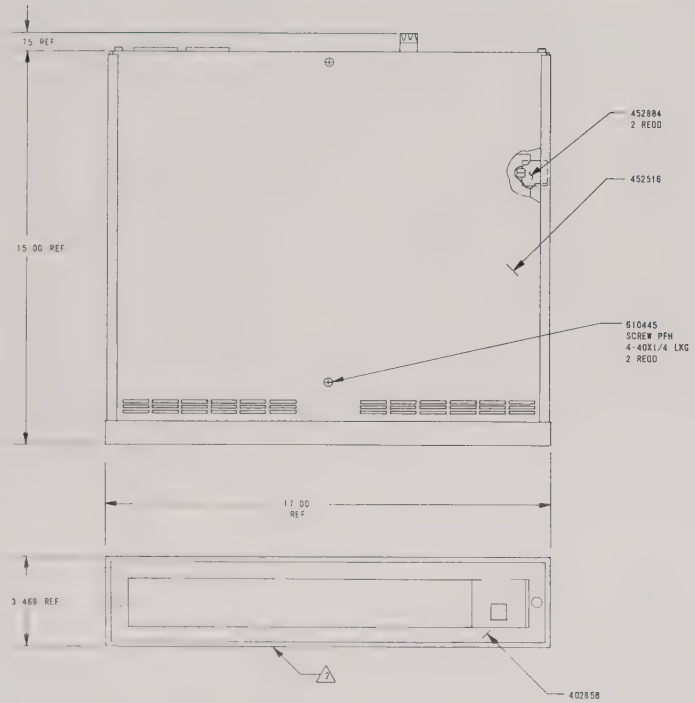
**DANA LABORATORIES INC.**
IRVINE, CALIFORNIA

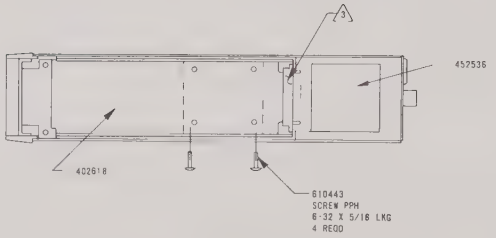
# SCHEMATIC POWER SUPPLY

| SIZE | CODE IDENT NO. | DWG NO. | REV |
|---|---|---|---|
| C | 21793 | 430713 | |

SCALE — WT — SHEET 1 OF 1

1 ALL RESISTORS ARE IN OHMS ± 5% 1 4W CARBON
NOTE: UNLESS OTHERWISE SPECIFIED




⚠ FOR WIRING DETAIL AND RECOMMENDED CABLE ROUTING SEE SHEET 3

⚠ FOR DETAILED ASSEMBLY OF MECHANICAL PARTS SEE SHEET 2

1 ASSEMBLY PROCEDURES AND PROCESSES TO CONFORM TO DANA WORKMANSHIP STANDARDS

NOTE UNLESS OTHERWISE SPECIFIED

| QTY REQD | DANA PART NUMBER | NOMENCLATURE OR DESCRIPTION | CODE IDENT | SPECIFICATION OR VENDOR P/N | ITEM NO. |
|---|---|---|---|---|---|

LIST OF MATERIAL OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON: DECIMALS: X .030, XX .010, XXX .005; ANGLES 0° 30'; FORMED ANGLES 1.0

CONTRACT NO.

DANA LABORATORIES INC.
IRVINE, CALIFORNIA

DRAWN J. M. Goldsmith 9/26/68
CHECK
DESIGN
PROJ ENGR

MATERIAL

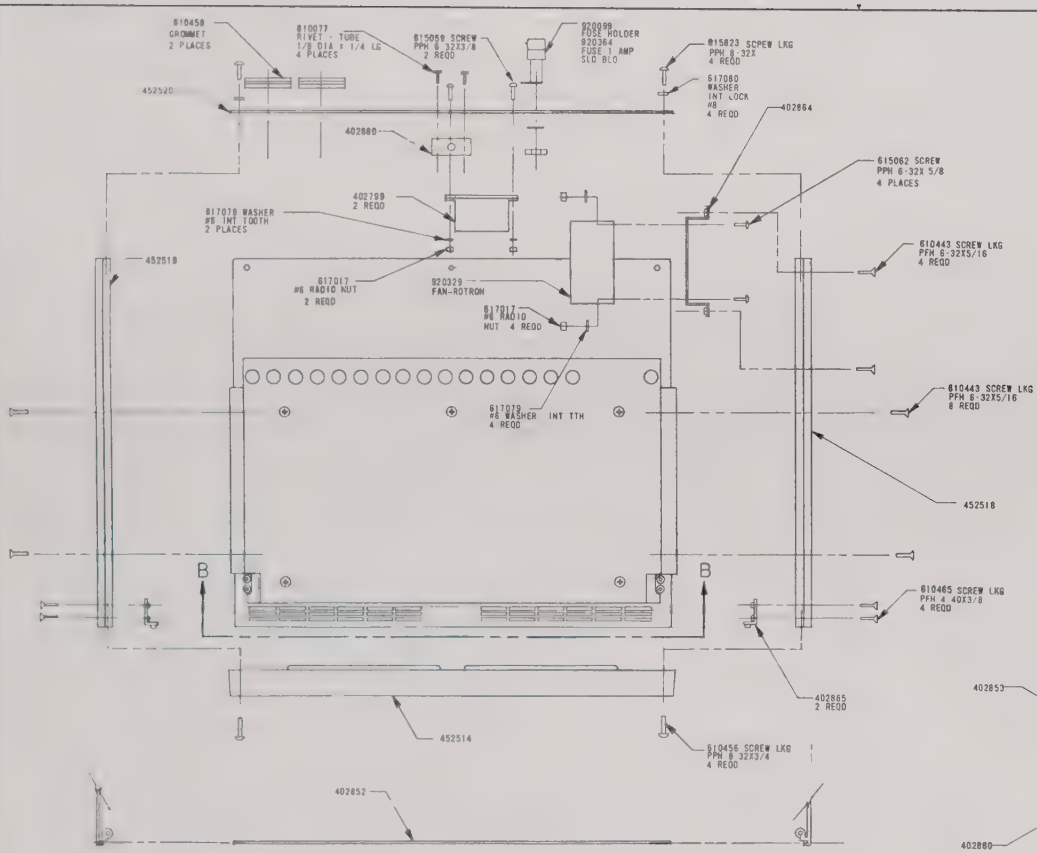
FINISH

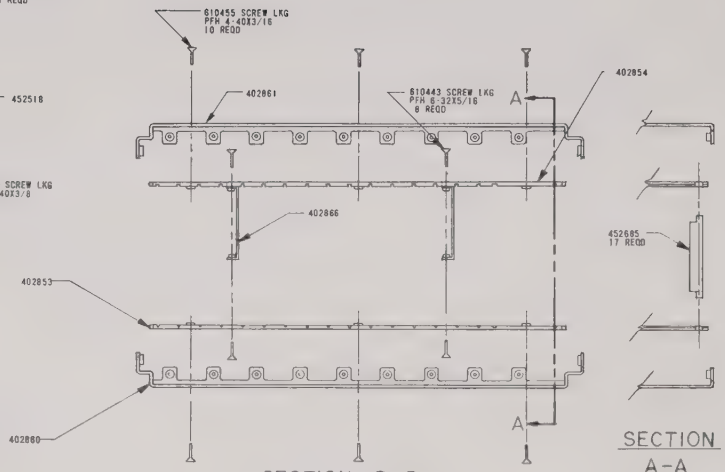
ENCLOSURE ASSY
MODEL 2616-1

| NEXT ASSY | USED ON | NA | FA |
|---|---|---|---|
| | 2616-1 | 1 | 1 |
| APPLICATION | | QTY REQD | |

| SIZE | CODE IDENT NO | DWG NO. | REV |
|---|---|---|---|
| D | 21793 | 402561 | |

SCALE 1/2 WT SHEET 1 OF 5


810458 GROMMET 2 PLACES
810077 RIVET - TUBE 1/8 DIA x 1/4 LG 4 PLACES
615059 SCREW PPH 6-32X3/8 2 REQD
920098 FUSE HOLDER 920364 FUSE 1 AMP SLO BLO
615823 SCREW LKG PPH 8-32X 4 REQD
617080 WASHER INT LOCK #8 4 REQD
452520
402880
402864
615062 SCREW PPH 6-32X 5/8 4 PLACES
402799 2 REQD
617078 WASHER #8 INT TOOTH 2 PLACES
610443 SCREW LKG PFH 6-32X5/16 4 REQD
452518
617017 #6 RADIO NUT 2 REQD
920329 FAN-ROTRON
617012 #6 RADIO NUT 4 REQD
610443 SCREW LKG PFH 6-32X5/16 8 REQD
617079 #6 WASHER INT TTH 4 REQD
452518
B
B
610465 SCREW LKG PFH 4-40X3/8 4 REQD
402865 2 REQD
452514
610456 SCREW LKG PFH 8-32X3/4 4 REQD
402852




SECTION B-B

SECTION A-A

| QTY REQD | DANA PART NUMBER | NOMENCLATURE OR DESCRIPTION | CODE IDENT | SPECIFICATION OR VENDOR P/N | ITEM NO. |
|---|---|---|---|---|---|

LIST OF MATERIAL OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON: DECIMALS | ANGLES | FORMED ANGLES
X .030 | 0° 30' | 1.0
XX .020
XXX .010

MATERIAL

FINISH

CONTRACT NO.

DRAWN J.M. Edwards 3/30/67
CHECK
DESIGN 4/26/67
PROJ ENGR 5/10/67

DANA LABORATORIES INC.
IRVINE, CALIFORNIA

ENCLOSURE ASSY
MODEL 2616-1

SIZE D | CODE IDENT NO 21793 | DWG NO. 402561 | REV

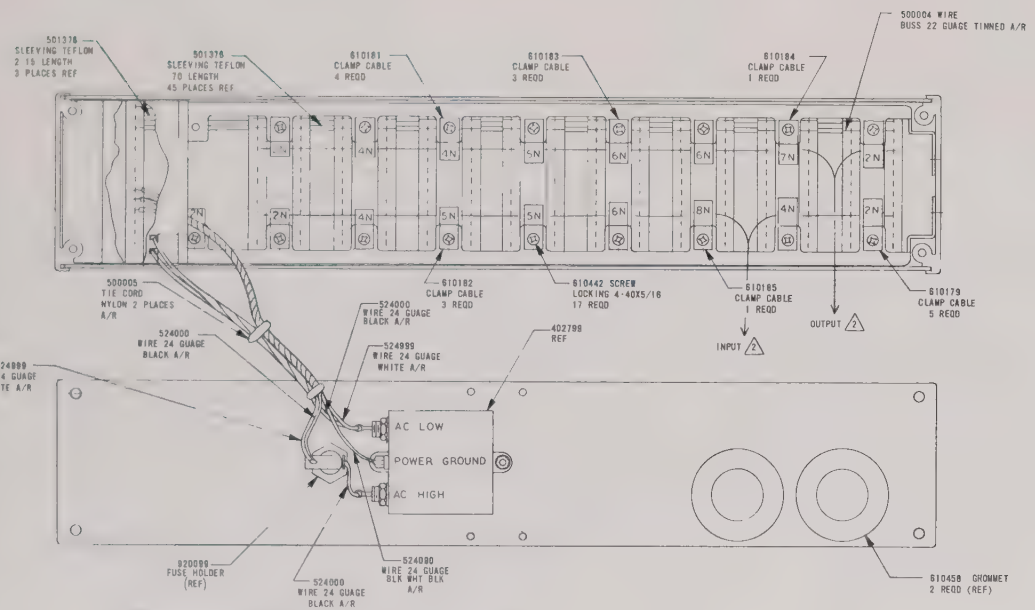
SCALE 1/2 WT | SHEET 2 OF 5

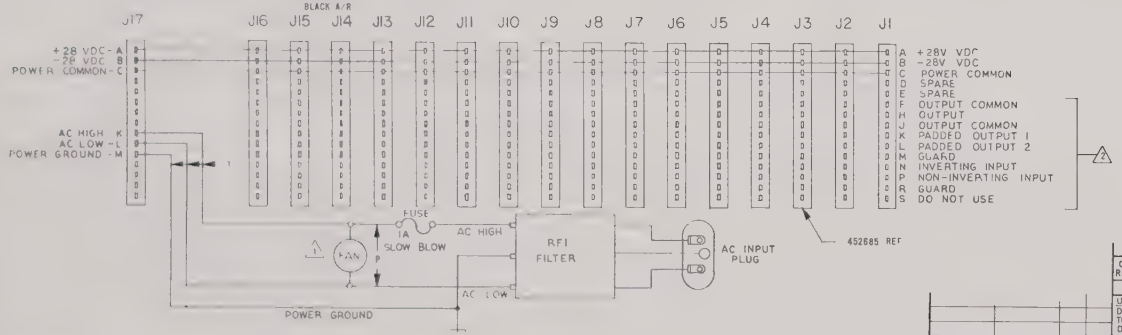
| 2616-1 | 1 | 1 |
|---|---|---|
| NEXT ASSY | USED ON | NA | FA |
| APPLICATION | | QTY REQD |

ASSEMBLY RECOMMENDATION: INSTALL ALL SCREWS LOOSELY FOR EASE OF ALIGNMENT PRIOR TO TIGHTENING

NOTE UNLESS OTHERWISE SPECIFIED

| REVISIONS | | | | |
|---|---|---|---|---|
| LTR | DESCRIPTION | DR | CHK | APPD |
| | | | | |


501376 SLEEVING TEFLON 2 15 LENGTH 3 PLACES REF
501376 SLEEVING TEFLON 70 LENGTH 45 PLACES REF
610181 CLAMP CABLE 4 REQD
610183 CLAMP CABLE 3 REQD
610184 CLAMP CABLE 1 REQD
500004 WIRE BUSS 22 GUAGE TINNED A/R
500005 TIE CORD NYLON 2 PLACES A/R
610182 CLAMP CABLE 3 REQD
610442 SCREW LOCKING 4-40X5/16 17 REQD
610185 CLAMP CABLE 1 REQD
610179 CLAMP CABLE 5 REQD
OUTPUT 2
INPUT 1
524000 WIRE 24 GUAGE BLACK A/R
524000 WIRE 24 GUAGE BLACK A/R
524999 WIRE 24 GUAGE WHITE A/R
524999 WIRE 24 GUAGE WHITE A/R
402798 REF
AC LOW
POWER GROUND
AC HIGH
820099 FUSE HOLDER (REF)
524000 WIRE 24 GUAGE BLACK A/R
524080 WIRE 24 GUAGE BLK WHT BLK A/R
610458 GROMMET 2 REQD (REF)




SCHEMATIC WIRING DIAGRAM

2 CABLE TERMINATION TO BE PERFORMED BY USER

1 ALL WIRING SHOWN IS PREWIRED PER DANA WORKMANSHIP STANDARDS.

NOTE UNLESS OTHERWISE SPECIFIED

| QTY REQD | DANA PART NUMBER | NOMENCLATURE OR DESCRIPTION | CODE IDENT | SPECIFICATION OR VENDOR P/N | ITEM NO. |
|---|---|---|---|---|---|
| | | LIST OF MATERIAL OR PARTS LIST | | | |

| NEXT ASSY | USED ON | NA | FA |
|---|---|---|---|
| | 2616-1 | 1 | 1 |
| APPLICATION | | QTY REQD | |

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
DECIMALS: X .030, XX .020, XXX .010
ANGLES 0° 30'
FORMED ANGLES 1.0
MATERIAL
FINISH

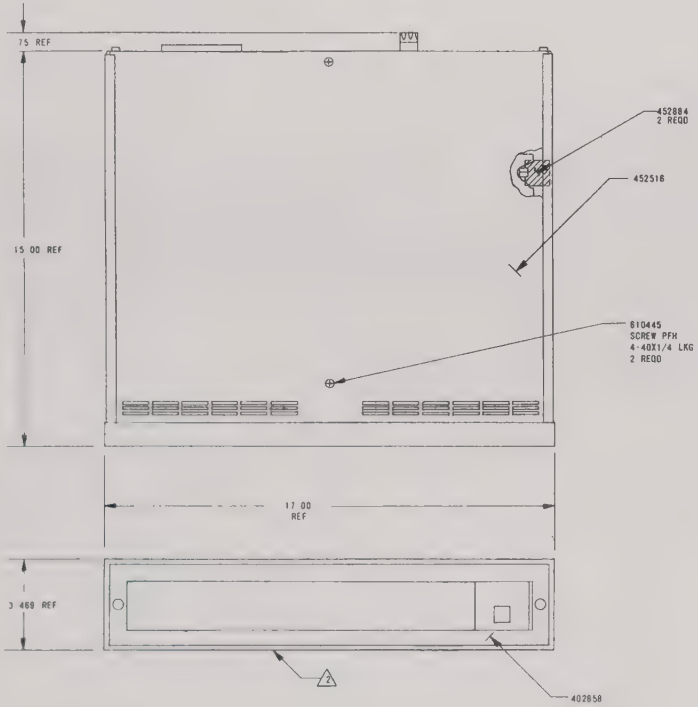
CONTRACT NO.

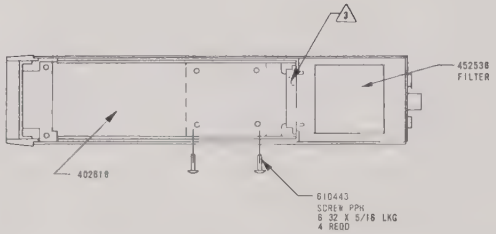
DANA LABORATORIES INC.
IRVINE, CALIFORNIA

DRAWN 3/13/68
CHECK
DESIGN
PROJ ENGR

ENCLOSURE — ASSY
MODEL 2616-1

| SIZE | CODE IDENT NO | DWG NO | REV |
|---|---|---|---|
| D | 21793 | 402561 | |
| SCALE 1 X 1 | WT | SHEET 3 OF 5 | |




3 FOR WIRING DETAIL SEE SHEET 3

2 FOR DETAILED ASSEMBLY OF MECHANICAL PARTS SEE SHEET 2

1 ASSEMBLY PROCEDURES AND PROCESSES TO CONFORM TO DANA WORKMANSHIP STANDARDS

NOTE UNLESS OTHERWISE SPECIFIED

| QTY REQD | DANA PART NUMBER | NOMENCLATURE OR DESCRIPTION |
|---|---|---|
| | | LIST OF MATERIAL OR PARTS |
| 1 | 2616-2 | |

| NEXT ASSY | USED ON | NA | FA |
|---|---|---|---|
| APPLICATION | | QTY REQD | |

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
DECIMALS: X ±.030, XX ±.010, XXX ±.005
ANGLES 0° 30'
FORMED ANGLES 1.0

MATERIAL

FINISH

CONTRACT NO.

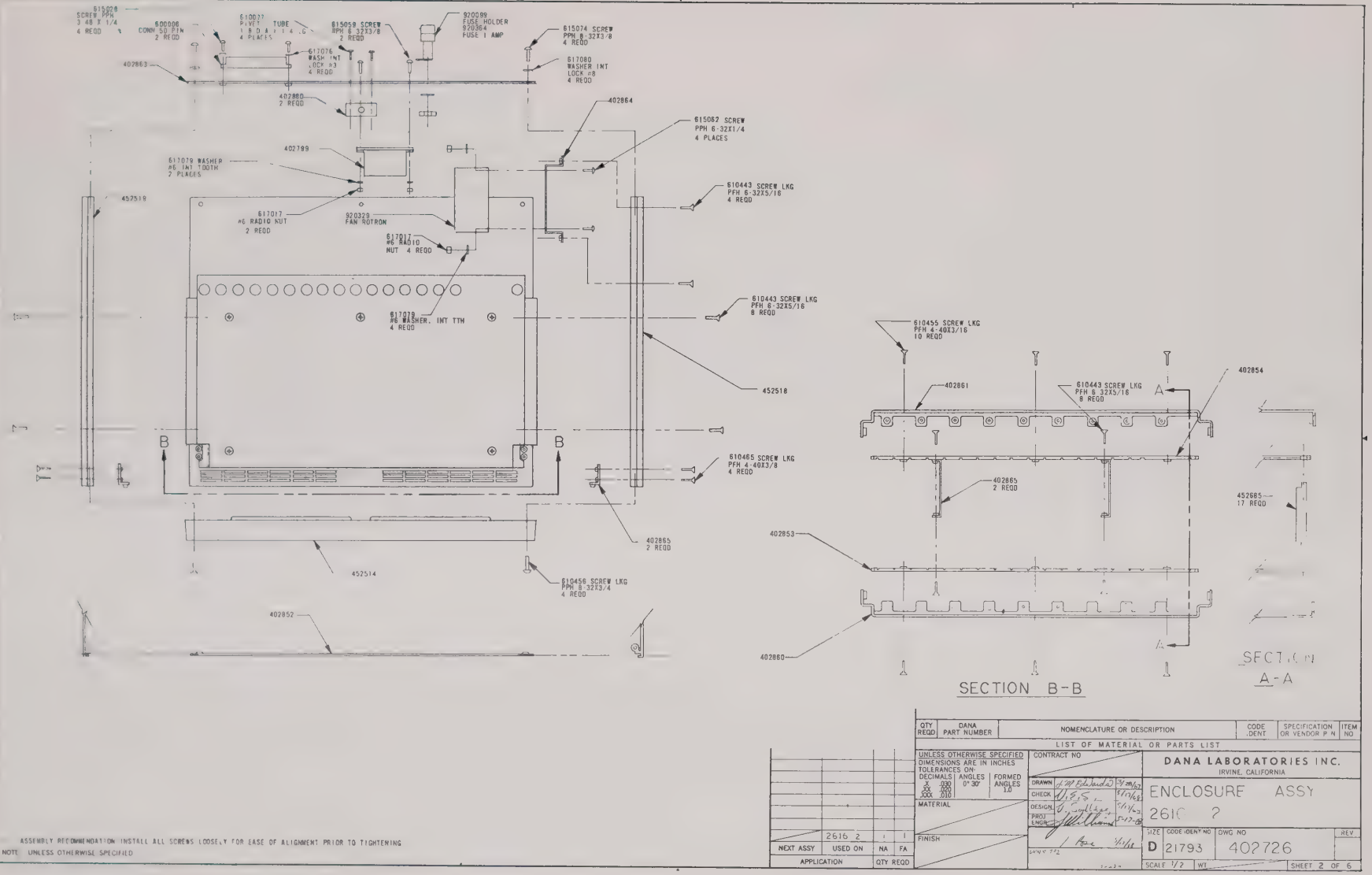
DRAWN J.M. Alexander 5/13/68
CHECK W.S.S. 5/17/68
DESIGN W.S. Sellers 5/17/68
PROJ ENGR [illegible] 5-17-68
DRAFTING J. Ross 5/16

DANA LABORATORIES INC

ENCLOSURE ASSY
MODEL 2616-2

SIZE D | DRAWING NO. 21793 | 402726 | REV

SCALE 1/2 | SHEET 1 OF 6


615028 SCREW PPH 3-48 X 1/4 4 REQD
600006 CONN SD PIN 2 REQD
610027 RIVET TUBE 1 B D A 1 1 4 .G 4 PLACES
615059 SCREW PPH 6-32X3/8 2 REQD
920099 FUSE HOLDER 920364 FUSE 1 AMP
615074 SCREW PPH 6-32X3/8 4 REQD
617080 WASHER INT LOCK #8 4 REQD
617076 WASH INT LOCK #3 4 REQD
402863
402880 2 REQD
402864
615082 SCREW PPH 6-32X1 1/4 4 PLACES
402789
617078 WASHER #6 INT TOOTH 2 PLACES
452519
617017 #6 RADIO NUT 2 REQD
920328 FAN ROTRON
617017 #6 RADIO NUT 4 REQD
610443 SCREW LKG PFH 6-32X5/16 4 REQD
610443 SCREW LKG PFH 6-32X5/16 8 REQD
617078 #6 WASHER INT TTH 4 REQD
452518
610465 SCREW LKG PFH 4-40X3/8 4 REQD
402865 2 REQD
452514
610456 SCREW LKG PFH 8-32X3/4 4 REQD
402852
610455 SCREW LKG PFH 4-40X3/16 10 REQD
402861
610443 SCREW LKG PFH 6-32X5/16 8 REQD
402854
402865 2 REQD
452685 17 REQD
402853
402860
SECTION B-B
SECTION A-A

ASSEMBLY RECOMMENDATION INSTALL ALL SCREWS LOOSELY FOR EASE OF ALIGNMENT PRIOR TO TIGHTENING

NOTE UNLESS OTHERWISE SPECIFIED

| NEXT ASSY | USED ON | NA | FA |
|---|---|---|---|
| | 2616 2 | 1 | 1 |
| APPLICATION | | QTY REQD | |

| QTY REQD | DANA PART NUMBER | NOMENCLATURE OR DESCRIPTION | CODE IDENT | SPECIFICATION OR VENDOR P N | ITEM NO |
|---|---|---|---|---|---|

LIST OF MATERIAL OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON- DECIMALS .XX ±.03 .XXX ±.010 ANGLES 0° 30' FORMED ANGLES 1.0

MATERIAL

FINISH

CONTRACT NO

DRAWN W. M. Edmunds 5-20-62

CHECK 5/21/62

DESIGN 5/14/62

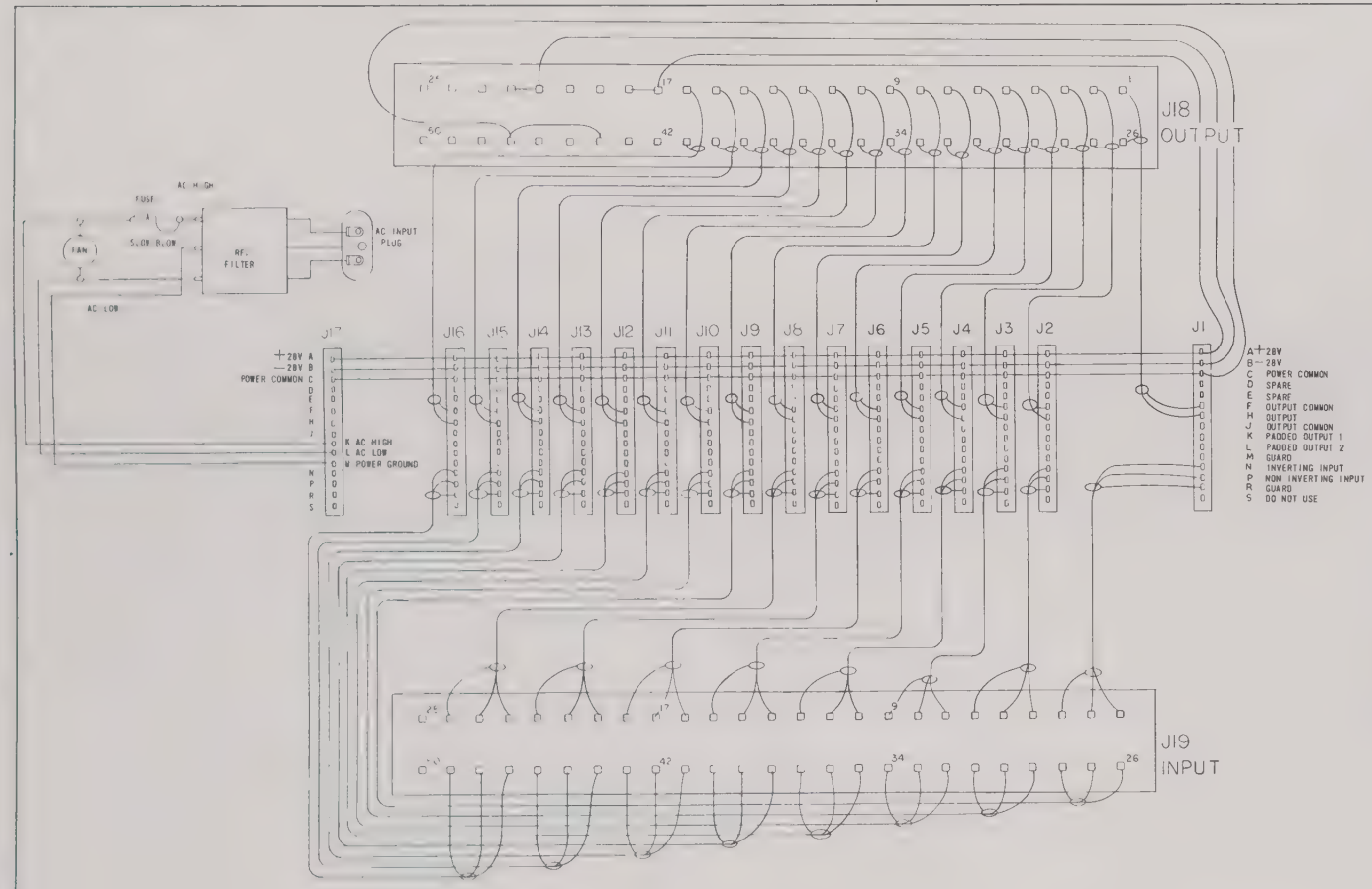
PROJ ENGR 5-17-62

DANA LABORATORIES INC.
IRVINE, CALIFORNIA

ENCLOSURE ASSY
2616 2

| SIZE | CODE IDENT NO | DWG NO | REV |
|---|---|---|---|
| D | 21793 | 402726 | |

SCALE 1/2 WT SHEET 2 OF 6




NPUT CONNECTOR

PIN

| | | | | | |
|---|---|---|---|---|---|
| 1 | CHANNEL 1 | NON INVERT | 26 | CHANNEL 9: | NON INVERT |
| 2 | CHANNEL 1 | INVERT | 27 | CHANNEL 9: | INVERT |
| 3 | CHANNEL 1 | GUARD | 28 | CHANNEL 9: | GUARD |
| 4 | CHANNEL 2 | NON INVERT | 29 | CHANNEL 10 | NON INVERT |
| 5 | CHANNEL 2 | INVERT | 30 | CHANNEL 10: | INVERT |
| 6 | CHANNEL 2 | GUARD | 31 | CHANNEL 10: | GUARD |
| 7 | CHANNEL 3: | NON INVERT | 32 | CHANNEL 11 | NON INVERT |
| 8 | CHANNEL 3 | INVERT | 33 | CHANNEL 11: | INVERT |
| 9 | CHANNEL 3 | GUARD | 34 | CHANNEL 11 | GUARD |
| 10 | CHANNEL 4: | NON INVERT | 35 | CHANNEL 12 | NON-INVERT |
| 11 | CHANNEL 4: | INVERT | 36 | CHANNEL 12: | INVERT |
| 12 | CHANNEL 4: | GUARD | 37 | CHANNEL 12 | GUARD |
| 13 | CHANNEL 5: | NON-INVERT | 38 | CHANNEL 13: | NON-INVERT |
| 14 | CHANNEL 5: | INVERT | 39 | CHANNEL 13: | INVERT |
| 15 | CHANNEL 5: | GUARD | 40 | CHANNEL 13: | GUARD |
| 16 | CHANNEL 6: | NON INVERT | 41 | CHANNEL 14: | NON-INVERT |
| 17 | CHANNEL 6: | INVERT | 42 | CHANNEL 14: | INVERT |
| 18 | CHANNEL 6: | GUARD | 43 | CHANNEL 14: | GUARD |
| 19 | CHANNEL 7: | NON INVERT | 44 | CHANNEL 15: | NON INVERT |
| 20 | CHANNEL 7: | INVERT | 45 | CHANNEL 15: | INVERT |
| 21 | CHANNEL 7: | GUARD | 46 | CHANNEL 15: | GUARD |
| 22 | CHANNEL 8: | NON INVERT | 47 | CHANNEL 16: | NON-INVERT |
| 23 | CHANNEL 8: | INVERT | 48 | CHANNEL 16 | INVERT |
| 24 | CHANNEL 8: | GUARD | 49 | CHANNEL 16 | GUARD |

OUTPUT CONNECTOR

PIN

| | | | | | |
|---|---|---|---|---|---|
| 1 | CHANNEL 1 | OUTPUT | 26 | CHANNEL 1: | COMMON |
| 2 | CHANNEL 2 | OUTPUT | 27 | CHANNEL 2 | COMMON |
| 3 | CHANNEL 3 | OUTPUT | 28 | CHANNEL 3 | COMMON |
| 4 | CHANNEL 4 | OUTPUT | 29 | CHANNEL 4: | COMMON |
| 5 | CHANNEL 5 | OUTPUT | 30 | CHANNEL 5 | COMMON |
| 6 | CHANNEL 6 | OUTPUT | 31 | CHANNEL 6 | COMMON |
| 7 | CHANNEL 7 | OUTPUT | 32 | CHANNEL 7: | COMMON |
| 8 | CHANNEL 8 | OUTPUT | 33 | CHANNEL 8: | COMMON |
| 9 | CHANNEL 9: | OUTPUT | 34 | CHANNEL 9: | COMMON |
| 10 | CHANNEL 10: | OUTPUT | 35 | CHANNEL 10 | COMMON |
| 11 | CHANNEL 11: | OUTPUT | 36 | CHANNEL 11 | COMMON |
| 12 | CHANNEL 12 | OUTPUT | 37 | CHANNEL 12 | COMMON |
| 13 | CHANNEL 13 | OUTPUT | 38 | CHANNEL 13: | COMMON |
| 14 | CHANNEL 14 | OUTPUT | 39 | CHANNEL 14: | COMMON |
| 15 | CHANNEL 15: | OUTPUT | 40 | CHANNEL 15 | COMMON |
| 16 | CHANNEL 16 | OUTPUT | 41 | CHANNEL 16 | COMMON |
| 17 | | | 42 | | |
| 18 | +28V DC UNREG | | 43 | | |
| 19 | +28V DC UNREG | | 44 | POWER SUPPLY COMMON | |
| 20 | | | 45 | | |
| 21 | −28V DC UNREG | | 46 | | |
| 22 | −28V DC UNREG | | 47 | POWER SUPPLY COMMON | |
| 23 | | | 48 | | |
| 24 | | | 49 | | |
| 25 | | | 50 | | |

NOTES UNLESS OTHERWISE SPECIFIED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS | ANGLES | HOLE DIAMETERS
X .030 | 0 30 | - .004
XX .020 | FORMED | - .001
XXX .010 | 1 0 |
MATERIAL
FINISH

| DRAWN | | |
|---|---|---|
| CHK'R | | |
| DESIGN | | |
| MECH ENGR | | |
| PROJ ENGR | | |

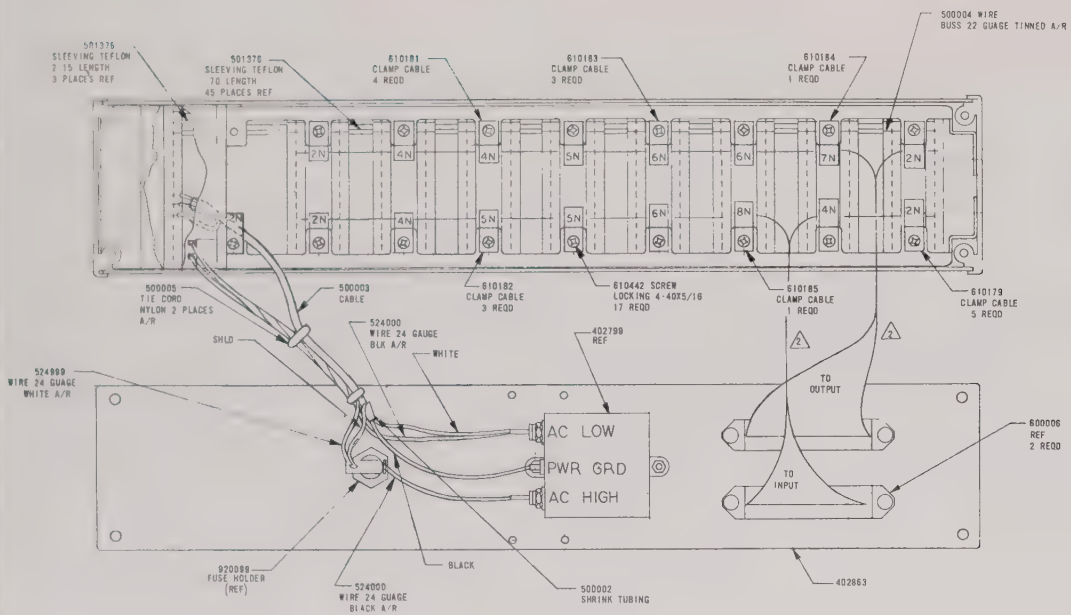
DANA LABORATORIES INC
IRVINE, CALIFORNIA

ENCLOSURE ASSY
MODEL 2616-2

| SIZE | CODE IDENT NO | DWG NO | REV |
|---|---|---|---|
| D | 21793 | 402726 | |

SCALE NONE SHEET 3 OF 6

| NEXT DWG. | USED ON | NEXT DWG. | FINAL ASSY |
|---|---|---|---|
| 2616-2 | | | |
| APPLICATION | | QTY REQD | |




| QTY REQD | DANA PART NUMBER | NOMENCLATURE OR DESCRIPTION | CODE IDENT | SPECIFICATION OR VENDOR P N | ITEM NO. |
|---|---|---|---|---|---|

LIST OF MATERIAL OR PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
DECIMALS: X .030, XX .020, XXX .010 | ANGLES 0° 30' | FORMED ANGLES 1.0

MATERIAL

FIN SH

CONTRACT NO.

DRAWN
CHECK
DESIGN
PROJ ENGR

DANA LABORATORIES INC.
IRVINE, CALIFORNIA

ENCLOSURE — ASSY

MODEL 2616-2

| SIZE | CODE IDENT NO | DWG NO | REV |
|---|---|---|---|
| D | 21793 | 402726 | |

SCALE 1 X 1 | WT | SHEET 4 OF 6

| NEXT ASSY | USED ON | NA | FA |
|---|---|---|---|
| | 2616-2 | 1 | 1 |
| APPLICATION | | QTY REQD | |

1. INPUT TO BE COAX CABLE (501448) OUTPUT TO BE (500003)
   SEE SHEET 3 FOR WIRING INSTRUCTIONS
2. ALL WIRING SHOWN IS PREWIRED
   PER DANA WORKMANSHIP STANDARDS.

NOTE: UNLESS OTHERWISE SPECIFIED

# *Warranty*

It is the practice of Dana Laboratories, Incorporated, to manufacture only products of a quality that will merit customer satisfaction. The company recognizes that customer satisfaction is achieved, not only by delivering products meeting advertised performance specifications and having a high level of reliability, but also by honestly and efficiently fulfilling their warranty obligations as set forth below.

Dana Laboratories, Inc., agrees to correct, either by repair or replacement, any defect of material or workmanship in Dana-manufactured units or components which develop within one year after delivery of the equipment to the original purchaser — provided that the equipment has been subjected only to normal and proper use.

In the event of failure of any component delivered with Dana equipment, but not manufactured by Dana Laboratories, assistance will be given the customer in obtaining, from the original manufacturer, reasonable adjustment under that manufacturer's warranty.

Any item claimed to be defective during the warranty period must be returned to Dana Laboratories, Inc., with transportation charges prepaid. The item will be repaired and returned to the purchaser with return transportation prepaid by Dana unless, of course, the item is found not to be defective or found to be damaged by misuse — in which case it will be returned to the purchaser with repair and transportation billed collect.

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